

A Semi-Monthly Technical Newspaper

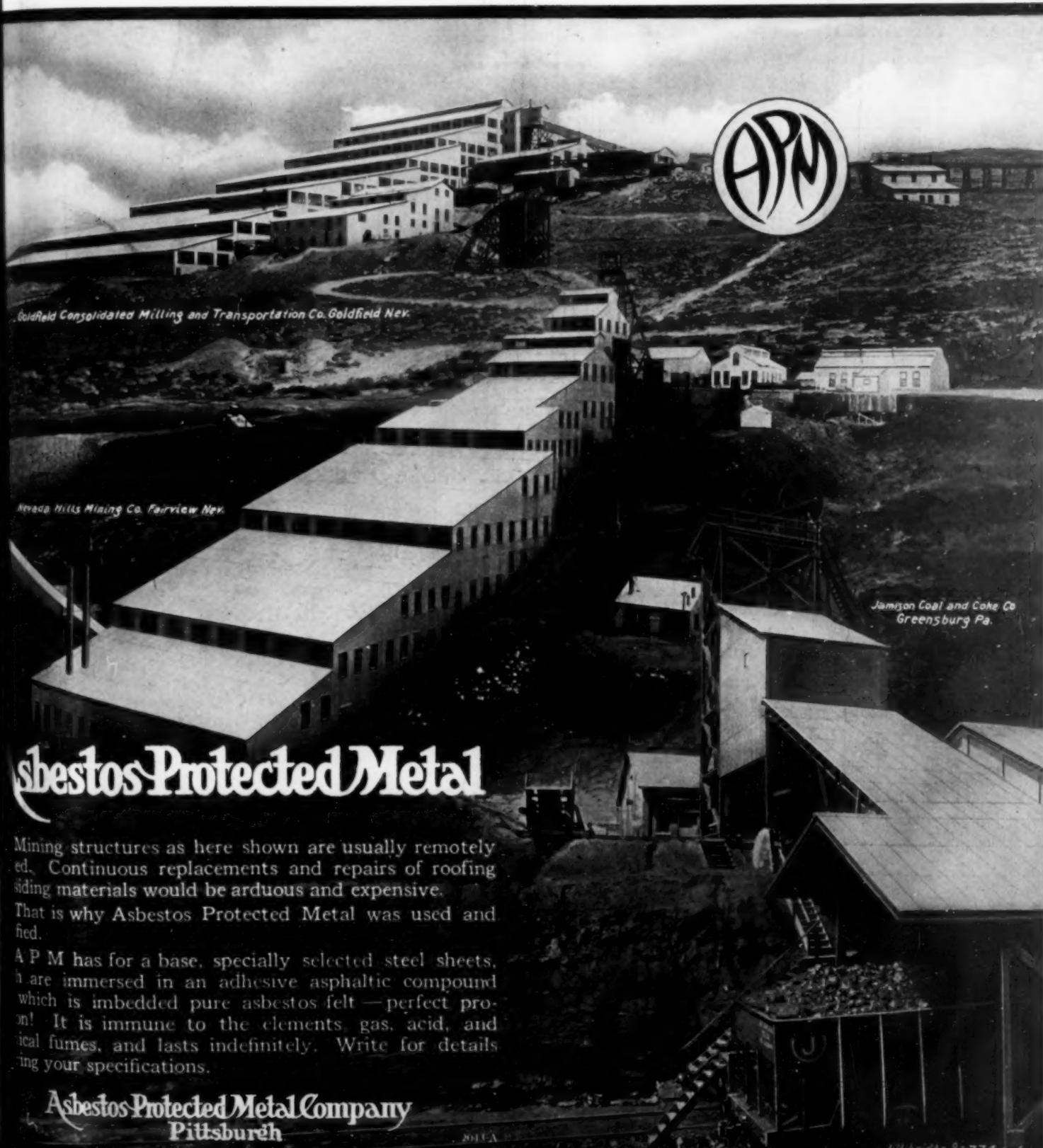
Metallurgical & Chemical Engineering

Volume XIV,

Number 11

June 1, 1916

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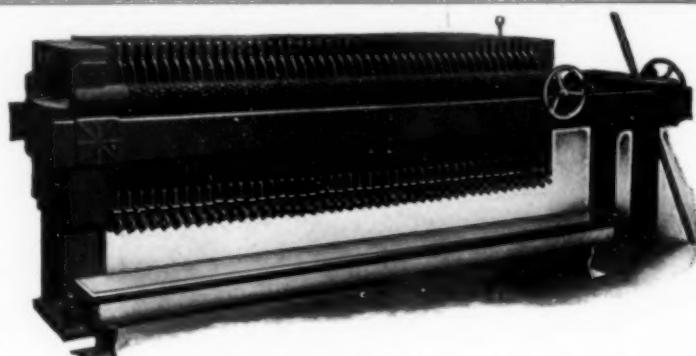
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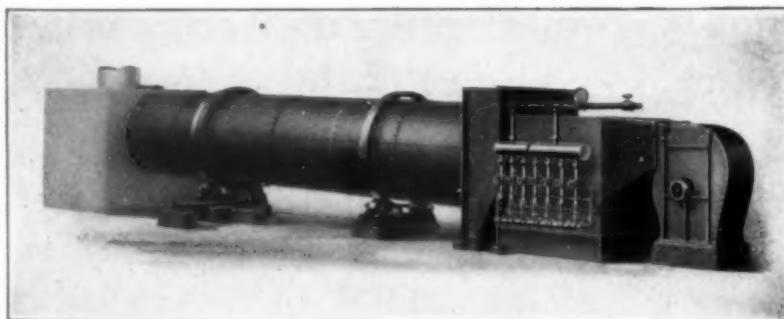
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7300 So. Chicago Ave.,
Chicago, Ill.

103 Richmond St. W.,
Toronto, Ont.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIV

NEW YORK, JUNE 1, 1916

No. 11

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH
OF EACH MONTH BY THE

MCGRAW PUBLISHING COMPANY, INC.

JAMES H. MCGRAW, President.

A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer
239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.
ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Col.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
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E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. MALCOLM MUIR, Manager.

Yearly subscription price for United States, Mexico and
United States dependencies, \$3.00; all other countries, \$4.00.

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Entered as Second-Class Matter at the Post Office at New York,
N. Y., under the Act of Congress, March 3, 1879.

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The Newlands Bill and Research

We have been very glad indeed to publish in our last issue and in the present one Dr. W. R. Whitney's two articles on the Newlands bill and research. As the distinguished chairman of the Chemistry and Physics Committee of the U. S. Naval Consulting Board, Dr. Whitney speaks authoritatively on the need of more research in this country. As the brilliant director of the Research Laboratory of the General Electric Company, Dr. Whitney is probably better fitted than any one else to say how research can be organized on a large scale so as to bring results.

We are very glad to see from Dr. Whitney's present article that representative scientific and technical men in this country are now expressing themselves practically unanimously in favor of the Newlands bill as the most sensible means of promoting research. To ourselves the feature which appeals most strongly in the Newlands bill is the logical manner in which the development of more research is to be attempted *ab ovo*, not starting at once with a big concentrated research institution, but with the creation of many nuclei of research spirit in the Land Grant Colleges all over the country. This country needs as much pioneer spirit to-day as in the days of our pioneer ancestors who founded this nation. But the pioneer spirit most needed to-day under changed conditions is of a different kind. Our country will take a good step forward toward the realization of its ideals, if the Newlands bill is adopted by an enlightened Congress.

The Chemistry of Flotation

The flotation process has been called a metallurgical anomaly, because it is so different from specific-gravity concentration. In ordinary water-concentration the lighter gangue is washed away from the heavier metallic particles, but in the flotation process the heavier metallic particles are floated. However, the "anomaly" is purely in the viewpoint of the millman who thinks of flotation in terms of specific-gravity concentration. He might just as well speak of electro-magnetic concentration as a metallurgical anomaly, whenever the magnetic particles are heavier than the non-magnetic particles from which they are separated. The fact is that in the flotation process an entirely new principle has been introduced into metallurgical practice which permits old things to be done in a new manner and which also permits a great many things to be done which could not be done before.

At the recent joint meeting of the New York Sections of the American Institute of Mining Engineers and of the American Electrochemical Society two very interesting papers were presented by Mr. George D. Van

Arsdale and by Prof. Wilder D. Bancroft on the how and why of flotation. Both papers were abstracted on page 572 of our last issue, and Professor Bancroft's paper is published in full on page 631 of our present issue. However they differed in the way of expressing their ideas, both authors were in complete harmony on all essential points and both discussed the how rather than the why of flotation. Mr. Van Arsdale defined flotation as that process of concentration which utilizes the different behavior of different kinds of solid particles with respect to surfaces of liquids and gases; flotation is surface action, and, such being the case, the chemistry of flotation must be closely allied with the chemistry of colloids. And exactly the same idea is expressed in Professor Bancroft's statement that ore flotation is not a unique phenomenon, but that it is merely a special case under the broad heading of emulsions. In laying so much stress on the many things which are analogous in one way or another to flotation, Professor Bancroft's paper should have the much-needed effect of dispossessing people finally of the idea that ore flotation is something unique in having laws of its own.

Whether one prefers to speak of the contact angle (as Mr. Van Arsdale does) or of the degree of wetting (as Professor Bancroft does), in either case the ultimate determining factor is the surface film on the particles. Both authors dealt at great length with this surface film. Mr. Van Arsdale pointed out that it may be either a solid or a liquid or a gas or an electrostatic charge or a combination of them. Professor Bancroft laid particular stress on the fact that in the surface film we have to do with selective adsorption. If a liquid wets a solid, it is adsorbed by the solid, forming a liquid film on the surface of the latter and displacing the air that was there. In many of the cases where oil flotation has been employed, the sulphide ore is more readily wetted by oil than water while the siliceous gangue is more readily wetted by water than by oil; consequently the gangue stays in the water phase while the ore is carried up by the oil. However, the problem of selective adsorption is here simply stated not solved; why are the sulphide particles more readily wetted by oil than by water? Nevertheless in some cases the adsorption-film theory brings us nearer to the why. If the surface of a copper wire be converted to sulphide, it will float more readily; we may simply state the fact and say that the contact angle is changed by the change to sulphide to facilitate flotation. Or we may go a step further with Professor Bancroft and say that the reason is that the adsorption of an air film is more marked with the change to sulphide.

The study of the selective adsorption of gases and vapors by solids and liquids will without doubt bring us in time much nearer to the discovery of some of the why's of flotation along the lines sketched by Professor Bancroft. And yet it must be doubted that it will supply the whole solution. The most open part of the whole theory is the question what part electrostatic surface films play in ore flotation, if any. There is no doubt that an electrostatic charge changes the contact angle in a definite manner; the capillary electrometer

would not be an exact measuring instrument otherwise. This is one firmly established fact. On the other hand, as J. M. Callow has pointed out (our issue of Jan. 1, 1916, page 49), there is a certain parallelism between electrostatic characteristics and the flotation properties of ores. Between these two sets of facts there is a wide gulf that needs to be filled. But from what we know of the electrostatics of colloids we may conclude that there must be some definite connection.

After all, the New York sections of the American Institute of Mining Engineers and of the American Electrochemical Society have done wonderfully well in getting together. If the pace set can be kept up, their annual joint meeting will become a classic event. Last year it was the Ricketts symposium on copper leaching; this year the Van Arsdale-Bancroft symposium on flotation. What next? The two sections did just the right thing in re-electing their respective chairmen, Dr. David H. Browne and Dr. Colin G. Fink.

Making Steel and Selling Steel

Not infrequently the steel works manager acquires a "grouch" against the sales department. He feels that the benefit of economies he has striven hard to effect are handed over to the buyer of the steel instead of being retained to enrich the company's treasury. Often there is reflection upon the sales department because it cuts a price a dollar a ton, perhaps several dollars a ton, when the works manager thinks in units of a cent or a tenth of a cent a ton.

It is natural for such criticism to go too far, through two points being overlooked. Whether the reduction in cost made by the works manager is given away by the sales department or not, the manager must introduce all the economies he can, for whenever he does not his works will begin falling behind. Another point is that a reduction in the cost of manufacture is a reduction per ton of output for an indefinite time in the future, whereas a cut price is only upon a limited tonnage. The aggregate value of a reduction of 10 cents a ton in cost of manufacture may be vastly greater than the aggregate loss of an unnecessary cut of \$1 a ton upon a specific number of tons involved in a given sale.

It is obvious, however, that operating departments are conducted more scientifically than sales departments. It is easier to see why this is the case than to see that it must always be the case. The difference in position is due to the fact that what is done in the operating department stays and must ultimately become public, while what is done in the sales department may be kept secret. Eventually it must be forgotten, while improvements in appliances and practices are to be seen and must eventually come to the knowledge of competitors. Knowing that his improvement must reach other works eventually, the works manager is frequently disposed to swap information, whereby both parties may gain.

Sales departments of rival producers do not correspondingly swap information. Occasionally they do make exchanges, but even then there is a tendency to withhold part at least of the truth. Statements with respect to sales cannot be tested for accuracy as well

as statements with respect to processes of manufacture, and the environments are such that circumstances compel works managers to be more accurate in their statements than is the case with sales managers.

There has been so much prosecution, and threat of prosecution, on account of alleged restriction in trade, that sellers of steel, as well as of other commodities, have become extremely reserved as to communicating with competitors. They have become unduly sensitive, because no clear guide was furnished as to what they were permitted to do and what they were not permitted to do. Of late, however, the situation has been growing clearer. The Department of Justice has approved certain practices, and the recently established Federal Trade Commission has been preaching co-operation among manufacturers. It is true this commission has no legal authority, but it has a great deal of influence. It is vigorously urging the adoption of more accurate cost accounting systems, for the direct guidance of those who make the sales and it strongly advocates trade associations.

The way is open, legally, for many reforms in sales methods, and it will be the fault of sales managers if the reforms are not effected. The real barrier at the moment is the indisposition to exchange information. In several branches of industry a system has been put in operation, with full sanction of the Washington authorities, whereby all sales of a given commodity are reported to a commissioner, who in turn circulates the reports to the contributors. The practice, where tried, has proved profitable to the participants, and it can be adopted in almost any branch of industry when the individuals are willing to participate. Another system of publicity which has proved efficacious in improving sales methods has been that of comparing production costs, whereby a composite cost of manufacture in a branch of industry is obtained. These methods employ psychology rather than force to improve sales practices. They enlighten sellers and remove misapprehensions. The sales manager, for instance, may have been disposed to ignore his own costs on the assumption that competitors had lower costs which he had to meet. Knowledge that those costs are not as low as surmised has often led to sellers demanding higher prices or refusing to make cuts, while knowledge that costs of competitors are lower leads to changes in methods of operation.

All this is enlightening publicity tending to improve sales methods. The selling of steel can be made more scientific and we believe it will be. The principle of exchanging information that has improved the industry of making steel must be adapted to the industry of selling steel.

All by the Way—of Three

Shakespeare once said, "All the world's a stage and the men and women merely players on it," and gave a list of the seven stages or seven ages of man. He brought in this way the mystic number of seven into his inventory of life. The ancients, too, delighting in a certain mysticism of numbers, placed astrological

importance on the numbers "seven" and "three." Numbers seem to be wonderful things on concepts, and the cardinal point is that numbers are cardinal and comprehend the idea of separate entities. In the red color there may be battle and blood, but, on the other hand, there is safety in cardinal numbers.

The number "seven" is then regarded as mystic, as is seen in the colors of the spectrum, but the number "three" is simple and is understood by men, for the human mind can grasp three things at one time, but not seven things. The old phrase, "The rule of three," we will see can be applied to many things besides arithmetic. Thus, we have a three-sided truss, the strongest mechanical configuration, and the three-phase current, the most stable "electrical structure." Let us just pause a moment in thought and consider how many triplets of verb, nouns, and adjectives we use in our ordinary and everyday life. Thus, in a business deal we have "discussion, negotiation, and execution." We "read, mark, and inwardly digest." A contract is "signed, sealed, and delivered." "Make ready, aim, and fire" is the martial order. Adjectives when strung in groups of three have a particularly sonorous sound and felicity of expression. Thus a man may be "good, bad or indifferent." In the nineteenth-century "twenty-question" game of children we all used to ask, first of all, "animal, vegetable, or mineral?" In grammar, too, we learned "past, present, and future."

We know that every human character and also human intelligence is derived from countless little, "see, think, and act" mental operations. Then we have the three dimensions of space, "length, breadth, and thickness." Indeed, if life is life, "all good things come in three." And the music of the waltz pervades love. So things seem to repeat themselves to mankind by the simple number three. The "positive, comparative, and superlative" are likewise three-fold.

The three "R's," "reading, 'riting and 'rithmetic," are well known. Then, too, those that follow the sea must know the "three L's," "lead, latitude, and lookout." The keen sailor used the "lead" to sound the bottom, his reckoning of "latitude" to know where his boat is, and the "lookout" to see ahead.

The rule of the number "three" pervades life in some way, and we should "stop, look, and listen," so that some evil things we have done twice we will do not thrice, and so that the good thing that we've made a "duo" may be made a "trio." In the language of the old song "Learning Mulvaney to Waltz" we know: "Now, one, two, three, come balance with me, your left foot is lazy, your right foot is crazy, but don't be 'unaisy,' your learning to waltz."

Now, indeed, seriously, more seriously, and most seriously, to use ourselves the rule of three in learning to waltz in our minds, and to preserve an equilateral triangle of psychological forces, we become balanced and poised. "One, two, three, come balance like me," is the simple refrain of an Irish comic song, but it comprehends, broadens, and intensifies "the rule of three" expressed, a trinity of "labor, love, life" to those that know how to live simply, silently, and sarcastically.

Readers' Views and Comments

Questionnaire on Flotation

To the Editor of Metallurgical & Chemical Engineering

As regards the questionnaire on flotation which was published in your issue of May 15, page 562, Mr. J. L. Bruce, manager of the Butte & Superior Copper Co., has suggested that the following problems be added to the questionnaire:

1. Agitation as affecting static electricity upon the flotation of minerals.
2. Effect of heating on flotation pulp, conductivity, static phenomena, and surface tension.
3. Effect of acid or other electrolytes in creating galvanic action through contact with minerals or metals used in vessel or agitators.
4. Comparison of flotation results upon different ores as illustrated by comparative results upon different mesh sizes of the same ore.

We are very glad to receive these questions from Mr. Bruce and sincerely hope that those interested in the subject will give them careful consideration and discuss them in either the form of a paper, to be presented at the symposium at the Arizona meeting of the American Institute of Mining Engineers in September, or else present a discussion of them at the meeting, either in person or in writing.

DORSEY A. LYON.

University of Utah,
Salt Lake City, Utah.

Screamers

To the Editor of Metallurgical & Chemical Engineering

SIR:—The council of the American Chemical Society lately ordained that a committee be appointed to consider the possibility of the organization of a publicity bureau. This shall have for its purpose the dissemination of chemical information, and serve as a check upon the misstatements so frequently appearing in the public prints. Something of the sort is sorely needed.

We are reminded by some miscellaneous reading of newspapers and periodicals that we have done of late, and by historical data and legends that scientific misinformation will creep into places of the most acknowledged enlightenment all unawares.

"If you see it in *The Sun* it's so" is a maxim that we learned when we were young and twenty, and we have always held to it—more or less. And yet we confess to an emotional jolt or jar when, a couple of weeks ago, we learned from a news item in *The Sun* that bromine, if dropped upon the sand, will cause it to develop great heat and to harden into stone. This is as we remember it; if we err in the particulars we pray for forgiveness. A few days later *The Tribune* gave in detail the remarkable discovery of a Mr. Morrison, of whom it is said that he is not a professional chemist, but that he maintained his own laboratory. It was a method of beating the oil companies by avoiding the use of gasoline in automobiles. Comparison is made between Mr. Morrison's invention and that of a Mr. Enright who, it seems, has developed a "green powder" that he almost—but not quite—sold to Henry Ford, and which has already developed a flurry on the curb market. "Mr. Enright," says *The Tribune*, "claims that he decomposes water, thereby obtaining his hydrogen—a process which has never yet been demonstrated." We thought we had come across some hydrogen in our day that had been obtained by the decomposition of water,

but now, as we enter into *The Tribune's* habit of thought, we are disposed to say that we must have been mistaken, and that the hydrogen probably came from the air. Or maybe from *The Sun's* bromine, or from its rocky sand. It is easy to get mixed up over these things. "Mr. Morrison," continues the newspaper, "generates his hydrogen by the union of water with a chemical," and we are informed that his theory is simple in the extreme. "The chemicals he uses are metallic sodium and ammonia.

When water comes in contact with the sodium, the chemical action, as explained by a chemist, takes place as follows:



We wonder who the chemist was who "explained" it? The valuable by-product was also noted, and the whole story fills us with desire to load up our old 1912 model with sodium, ammonia and water and take a lovely springtime drive up in Westchester County around the Bloomingdale asylum, and then come back and get rich selling nitrate of soda to the fertilizer people.

The New York *Times* is usually very careful of its news, and we have great confidence in whatever it says, but we are in the throes and wallops of doubt about the following, which appeared on May 25. Under the scare head that "Rockefeller Riches Back Air Nitrate Co." it states with great gusto that liquid air is to be produced in this country. The new company has eight plants in operation and seven in process of construction to make liquid oxygen. "Plants for the extraction of nitrogen from the air for the conversion of nitrogen into cyanamid and the production of nitrates by the Claude process may be begun at any time. . . . The extraction of nitrogen requires much more power than the extraction of oxygen." There we have it! They "extract" liquid oxygen from the air by low power and they "extract" liquid nitrogen from the air by high power. Why didn't they ask somebody about this? The change of a few words would have made the article readable, reasonable and true. As it stands it misleads the layman and makes the chemist sigh.

In the June number of *The American Magazine* there is an interesting article on "Ambitious Business Men Rising to a New Opportunity," which treats in part of the same subject. It is a good article, and we are glad to see the kind printed in the magazines, except for the bulls that will creep in when any one of thousands of men right here in New York would have gladly eliminated them by a single reading. For instance, it is indicated that nitrogen may be "fixed" by making liquid air. And again: "The process consists in reducing the air to a very low temperature by means of powerful compressors." Of course, the compressors were there and the author saw them, but just a little advice would have made it right instead of wrong. This reminds us of the inventor who had a plan to establish a very high temperature by the rapid compression of hydrogen and then maintaining the heat by letting the hot gas escape.

Another hydrogen expert appeared before the managers of the Chemical Exhibition last fall with a master thought. "It takes 80,000 cu. ft. of hydrogen to lift a balloon," said this man of vision. "Very well, I plan to compress hydrogen in units of 80,000 cu. ft. into small cylinders. Then fasten as many of these cylinders as you please to an airy-o-plane, and up she'll go." Still another appealed to a patent lawyer with a plan to make ammonia from gasoline. "But where's your nitro-

gen?" asked the lawyer, as he proceeded to write down C_nH_{2n+2} . "Hell!" exclaimed the pious prophet of nature. "There's nitrogen to spare. Look here," and he proceeded to rewrite $CNH_2N + 2$. Lots of nitrogen!

But, alas! it is not alone among tufted inventors and astute and lively reporters and experts on popular heart throbs that the things go wrong. When Willard Gibbs was professor at Yale he read his original paper on the phase rule before the Connecticut Academy of Science. It was, as we recall it, sometime in the middle seventies. Nobody seemed to pay any attention to it. Old Gibbsey was a theorist, anyway. Then, about twenty years afterwards, the elder Ostwald, following the footprints of Gibbs, discovered the paper among the forgotten archives of the academy, which he translated into German and published with all credit to the author. Thus we have learned of the phase rule first from the German translation. Of what nature was the long slumber of the learned Connecticut Academy? The Yale professors of chemistry and physics must also have been sleeping soundly to leave this great treasure at hand all unnoticed.

But we do not have to abide within the domain of science to find more examples. A man named Jarves had lived long in Italy. He collected paintings of the primitives, and brought them back to America. In time he became financially embarrassed. There were no museums of importance here at the time, so he went to Harvard and offered his priceless collection as a pledge to any well-wisher of the university who would loan the sum needed, the pictures to become the property of the corporation in case he should default in payment. Harvard was not interested. Mr. Jarves was not a Boston man. Then he took the pictures to Yale, and finally he secured \$20,000 from a Yale benefactor against his note and collateral. When the debt matured he could not meet it, and he died in an agony of disappointment. Over his grave arose the humor of the situation. Yale was stung for fair! Twenty thousand dollars that probably would have come in to Old Eli, now wasted in paying that dead man's debts, and what had they to show for it? A lot of junk! Those skinny old saints and angels were the laughing stock of college life. There were cat-calls and moans for those bunches of bones. Finally, after many years, a man came along who told the learned authorities about those pictures, of their almost incalculable value, how no more could be brought out of Italy for love or money, and of a bid of \$20,000, still good, for the least important piece of the whole collection. The \$20,000 bid seemed to wake the authorities up. Now if you go to New Haven you must not fail to see the Jarves collection of Italian primitives. They are wonderful, and they are kept in a fireproof gallery specially built for them. Yale is justly proud of her great treasure. But where were the learned professors of mediæval history and art all those years?

No, it is too bad, really too bad that there is so little contagious curiosity around. That *American Magazine* article is good and useful; it tells many things that it is well for industrial chemistry to have told. It is excellent, too, that *The Tribune* and *The Sun* print articles about chemistry, even if they do contain statements that startle. What we deplore is that the truth seems to have so little standing in the editorial mind in regard to things scientific. Indeed, facts seem to be out of favor. On the other hand, things that are beyond the range of possibility appear on front pages, adorned with scare heads. We do not pretend to say that this is so for the same reason that little children prefer to hear fairy stories rather than authentic history. The whole thing baffles us. We observe, how-

ever, an utter lack of curiosity on the part of those who issue the public prints to find out whether a scientific statement is right or not. It would be easy enough to find out. The editors of technical journals are always willing to be interviewed by sincere reporters, and so are the many professors and instructors of science. The Chemists' Club is surely not discouraging to scientific inquiry, and if anybody were to go there burdened with an elementary question in chemistry he would not be turned away. That is what the library is there for. There are plenty of opportunities for writers on New York publications to get their questions answered willingly. The trouble is they do not ask.

PETER TEN BROECK.

Chemistry and Daily Papers

To the Editor of Metallurgical & Chemical Engineering

Sir:—In the New York Tribune of Sunday, May 14, 1916, in which the Preparedness Parade held in New York City the day before was appropriately and extensively treated, there appeared as a leading editorial "Water Power and Preparedness," based upon the Washington, D. C., meeting of the American Electrochemical Society and its symposium on Niagara water power. In the course of this editorial occurred the following statements:

"It is perhaps not unnatural that the public is ignorant of its interest in this vital question. Engineers and technical men are themselves largely responsible for the popular apathy since they have left the matter in the hands of ignorant legislators and met the restriction of power development with what could at best be described as passive resistance. . . . Yet our only hope at present is in the scientific and technical men. They have been too easy-going and have not taken sufficient pains to explain their aims and purposes to the public. It is only by doing so that they can hope to bring pressure to bear on legislators. . . . In the recent meeting of the American Electrochemical Society there were signs of a clearer realization among technical men of their public responsibility in this matter. This all to the good, for it is only through their efforts that the public can be made to understand what they have a right to demand of their legislators."

Speaking from my own personal experience I am convinced that the editors of our own daily papers are themselves in good measure responsible for the conditions referred to in the above quotations. In February, 1911, acting as Secretary of the Eighth International Congress of Applied Chemistry, to be held in Washington and New York in September, 1912, I sent to the editors of the daily papers in New York, Philadelphia, Boston, Baltimore, Washington, D. C., Chicago, Pittsburgh, St. Paul, Minneapolis, Omaha, Kansas City, Denver, San Francisco, and other cities, a short history of the seven preceding Congresses and statistical information as to their labors, also copies of our first pamphlet describing our aims and purposes and organization; in all 390 dailies all over the country were so approached. So far as I was able to learn, only two papers in two different states, both west of the Mississippi, took any notice whatever.

In June of that year I followed the February material up with more material and gave a short abstract of what we had accomplished and of what we hoped still to do, and sent that also to these same papers and about 150 boards of trade and chambers of commerce, and 8,000 manufacturers all over the country. At intervals thereafter I reported progress to the daily press in about the same way. Up to the summer of 1912, not one single New York daily took the slightest note of the matter sent to them. During that summer one daily did say something about the Congress, but only because we made very great personal effort to arouse the interest of that paper.

During the summer of 1912 one other New York daily did give about a quarter column to the Congress, printing a clipping out of the Consular Reports; but this clipped matter reached the Consular Reports because our Consul at St. Petersburg, Russia, with whom I had been in very active correspondence about the Congress, sent this matter to Washington as a news item. I had sent precisely that same information to that same New York editor eight months before, but it had no value to his paper until he found it in the Consular Reports, even though it was then more than eight months old.

When the Congress program was ready, I sent copies to every New York paper and as I recall it only two took any notice during its sessions of what the Congress was trying to do. Toward the end of its session they became a little more interested, but only in a lukewarm way. During this Congress two public lectures were given, whose combined attendance was something over 3000; at the first of these lectures an exhaustive and illustrative treatment was given of the Norwegian process of making nitric acid from air; at the second lecture an experimental demonstration of the synthetic production of ammonia was given; these two things are probably as great achievements as have been accomplished within the last generation, yet the New York dailies took no note of it whatever, and it was not until a clever Chicago reporter lampooned it that the press took notice of it; the only way that synthetic nitric and synthetic ammonia could break into our daily papers was through such an extravagant statement, as, for instance, "Chemists make Eggs out of Air"; it certainly is a very long way from synthetic ammonia and synthetic nitric to synthetic eggs.

This Congress was by no means a negligible affair; twenty-eight countries took part in it; eighteen different countries had organizations for preparation for the Congress, and these foreign organizations comprised 573 individuals and fifty-five societies. The American organization numbered upwards of 1500 technical and scientific men whose purpose was to promote the interests of the Congress. We distributed our news service to 438 trade, technical and scientific publications the world over, and this exclusive of our news service to the daily press; altogether we sent out over 300,000 pieces of printed matter informing the public what our aims and purposes were; 151 public meetings were held in New York City during the week this Congress was in session.

At the New Orleans meeting of the American Chemical Society, in March and April, 1915, that is, after we had had eight months of the great war, there were nineteen short papers presented, each of them wholly in non-technical language, on what the American chemists had done for nineteen American industries; advance proofs of each of these papers together with a short résumé of each of them, and all printed, were sent to the editors of about thirty prominent dailies inclusive of New York dailies; outside of New Orleans I could find but one daily that took any notice whatever of the matter and that was done by the simple process of "lifting" one of the articles as an editorial without giving any credit whatever to the American Chemical Society.

The first point of entry for publicity *must* be by way of the editors of our dailies; if they block the way nothing can be done. We must first educate our editors as to what the country should know, and then induce the editors to educate the public. The editors know better than any one else the mechanism for educating the public; if the editors will receive technical matter in a welcoming way, it is absolutely certain that the technical men will state their case in the lan-

guage and form which the editors consider best fitted for instructing the public. I say this, even though it has happened to me that after spending nine hours with an efficient editorial writer of a large New York daily, in explaining technical matters to him and in going over his manuscript and his copy and had boiled down a very technical story into fewer than 1500 words, our combined effort was crowded out by the editor-in-chief because he needed the space for something else. However, I am not discouraged; I still believe that our editors can be educated up to the point of wanting technical matters, and if the editors will come only one-third the way, the technical men will gladly go the rest of the distance.

BERNHARD C. HESSE.

New York City.

The Nitrogen Industry

To the Editor of Metallurgical & Chemical Engineering

SIR:—In a number of magazines and papers in this country there have appeared in the last few weeks a series of articles dealing with the nitrogen industry.

Most of these articles deal exclusively with the three different processes for the fixation of atmospheric nitrogen, namely, the carbide-cyanamid process, the arc process, and the Haber process, leaving out all the other industries manufacturing nitrogen or ammonia, for instance, the by-product coke ovens. This industry has made enormous progress in the United States in the last few years and produces to-day about 50,000 tons of ammonia per year in form of sulphate of ammonia or ammonia liquor, while the production in 1905 did not exceed 16,000 tons of ammonia. The United States cokes nearly as much as England and Germany combined and if all coke ovens had been by-product coke ovens the total output of nitrogen would have been nearly 200,000 tons.

Regarding the fixation of the atmospheric nitrogen, we will find statements which may give the impression that the carbide-cyanamid production is the only nitrogen industry fitted for this country, and that neither the arc process nor the Haber process can compete with the cyanamid process for the manufacture of nitric acid and its derivatives or of ammonia. The cyanamid process requires about 2.5 hp.-year for 2000 lb. nitrogen. The arc process in its present stage requires about 10 hp.-years per 2000 lb. nitrogen, or four times as much as the cyanamid process. The Haber process requires less than 0.2 hp.-year per 2000 lb. nitrogen, or about one-twelfth of the power required by the carbide-cyanamid process.

The cyanamid process and still more the arc process depend thus upon cheap power, while the power used by the Haber process is negligible, and without any influence on the cost of the final product.

Taking the arc process and the carbide-cyanamid process, the former uses, besides power, only air and water as raw materials, while the latter uses, besides power, lime, coke, coal, electrodes, nitrogen, etc., some of these raw materials in considerable quantities. By making, for instance, nitric acid by the cyanamid process, we have to produce carbide, cyanamid and ammonia, and from this, by oxidation, weak nitric acid, which has to be concentrated by means of heat supplied by coal, consequently a great number of operations which use a lot of workmen and cost money. By the arc process, we obtain at once weak nitric acid, which, by means of the heat developed by the furnace, which thus does not cost anything, can be concentrated to 98 per cent acid.

The arc process requires very few workmen and is comparatively a very much simpler process than the

carbide-cyanamid process. In fact, the main cost is the power. Detailed estimates on both processes show that the nitric acid, with steam power produced from coal at \$1.00 per ton, can be produced just as cheap by the arc process as from cyanamid, and there is, no doubt, in the United States an enormous amount of water power that can be developed at such cost as to deliver the power considerably than a steam plant located at the coal mines.

Supposing a nitric acid factory is erected for the purpose of delivering acid for war purposes; such a factory would in peace time deliver cyanamid, if the cyanamid process is applied, and nitrate of lime, or better, nitrate of ammonia if the arc process is applied. Nitrate of ammonia is an excellent fertilizer material that, on account of its concentrated form (42 per cent ammonia), can stand a heavy freight. The arc process utilizes at the present in Norway about 360,000 continuous horsepower, corresponding to a production of about 36,000 tons of nitrogen. Smaller factories using the arc process are also under construction in Spain, France and Germany. A big project for utilizing more than 100,000 electric horsepower produced by steam is under way in Germany and there is also a scheme using water power under way in Russia.

Of course, each of these schemes has been thoroughly examined as to their economical outlook in competition with the other processes, and there is no reason whatever why the arc process should not be applied in this country for the production of nitric acid in competition with the cyanamid or any other process.

The main reason why Germany has increased the production of cyanamid to such an enormous extent during the war is due only to the fact that she was obliged to do so. When the supply from Chile was cut off, Germany faced a serious situation and had to secure nitrogen from all possible sources in the most limited time. The cyanamid process was chosen for the supply of nitrogen that could not be covered immediately by the Haber process, because it does not require more than one-fourth of the power of the arc process and thus can be constructed in shorter time and while water powers are very scarce in Germany. The demand of the German cyanamid group for the establishment of a nitrogen monopoly in Germany as a condition for the extension of their plants seems to be due to the circumstances that the cyanamid group wishes to secure their industry for a period after the war.

Turning to the Haber process, we will find that this process does not depend upon power at all, and the belief that the Haber process uses fully half the power required by a well-constructed carbide-cyanamid plant is not correct. The sole product by the Haber process is ammonia, from which nitric acid, all kinds of nitrates and sulphate of ammonia can be produced just as well as ammonia from cyanamid. The number of workmen used by the Haber process for producing ammonia is considerably less than used by the cyanamid process. Skilled labor is required to about the same extent as by the cyanamid process.

There is no reason why the Haber process should not be operated in this country just as economically as in Germany. Dr. Bernthsen, in his lecture on the Haber process at the Eighth International Congress of Applied Chemistry in September, 1912, made this statement: "There is every reason to assume that this industry will find a fruitful field of employment in America, where the demand for nitrogen-manures will soon be greater than hitherto."

Since that time, the Badische has erected factories in Germany, using the Haber process, with a production

of more than 75,000 tons of ammonia, while in 1912 the production was only 7500 tons of ammonia.

The cost of production of ammonia with the Haber process is able to compete with any other processes. On account of the war, the Badische has not made any attempt to introduce the Haber process abroad.

To sum up the above, there is no reason whatever why all of the three processes for the fixation of atmospheric nitrogen should not be operated in this country, as they have been in Europe, and it requires a thorough investigation of each single case in order to decide which process should be applied. To believe that only one of the processes is suitable for the United States is to overlook many considerations and to underestimate the resources of this country.

SYSTEN BERG.

New York City.

The Newlands Bill and National Research

BY WILLIS R. WHITNEY

Some two hundred representative men of science in the United States have been requested to give their opinions upon the Newlands Bill as an initial step in the national organization of research. Of over sixty replies already received only seven have been otherwise than heartily favorable.

The objections raised in these seven letters fall into three classes, in order of emphasis as follows:

1. The grants will in many cases fall into the hands of untrained men and institutions, and not be employed to good advantage.

2. Small grants distributed to the separate colleges will not be nearly so effective as the total sum devoted to one central organization.

3. The term "Engineering and Mechanics Arts" neglects Chemistry.

To the last criticism it may be replied that however little chemistry may be mentioned it will still get its due, because it is an absolutely essential factor in almost all problems. Few indeed are the researches which do not involve chemical investigation at some point.

In regard to the other two objections, have not certain extremely important factors in the situation been overlooked? If the research accomplishment of the future is going to be limited to the circles of influence of just those men, universities and laboratories which have so far shown themselves relatively efficient, is not the growth of new knowledge going to be about as slow as during the last decade? Have we any reason for believing that the potential talent of the country is so segregated either geographically, or by financial resource, that all that is good, or even a relatively large proportion of it, may fall under the influence of these few selected men and institutions? The potential research man is not a distinct type. He wears no mark, for himself or others to recognize, and if removed some hundreds of miles from any example of research, is he not pretty likely to follow a nearer example, and be lost to this field which needs him so much? If America is to take her proper place in the world she must produce advanced workers at a much faster rate than ever before.

To do this she must draw into the ranks of research more of the suitable minds which we have no reason to doubt exist among our people.

Suppose a certain land grant college has never produced research. Is the grant of a sum for the purpose going to make it less likely to produce? Such a college is an undeveloped field. Is it not possible that it can be made productive, and is it not good policy to try? The large and thriving institutions hold no complete monopoly of talent nor of right to assistance. Why not

encourage the little fellows to realize their possibilities?

Our necessity is not alone for more men to perform research. It is equally for more men who know the significance and aspect of research, and so understand its possibilities. In a democracy, advance in any direction whatever, is only possible through the conviction of the average man that it is desirable. Research in its national aspect can never be served by constituting it an aristocracy of men or of institutions. It must rather become the familiar tool whose use all may know and welcome, even though an understanding of its inner mechanism may require an expert.

I will let some of those who favor the bill as a constructive measure answer the objections in their own words.

Prof. Edward W. Morley, Western Reserve University: "I feel about the Newlands Bill, as I judge you also feel, that it is at best a small beginning at a complicated and difficult matter; that it at least is a beginning; and that it should therefore receive the cordial support of all of us who know how immensely important scientific research is to the welfare of the country."

Prof. Ira Remsen, Johns Hopkins University: "Your circular letter of April 29 with the enclosure was received a few days ago. A careful reading of both leads me to the conclusion that the Newlands Bill is for the interest of science and therefore in the interest of the country. It has my hearty approval."

Prof. William T. Sedgwick, Mass. Institute of Technology: "I heartily concur in your scheme for establishing Engineering Experiment Stations in the colleges, and sincerely believe that this would be an admirable way to set going a large amount of useful research work in this country."

William Brady, Chief Chemist, Illinois Steel Company: "I have felt for a long time that the Government should support industrial research. I saw no real practical way of doing it. A Bureau at Washington did not appeal to me as just the right procedure. I do feel, however, that the work should be supported by our National Government and be under Government control."

"The proposed bill is more in accord with my ideas on the subject than any scheme that has yet come to my notice."

W. C. Geer, of the B. F. Goodrich Company, Akron, Ohio: "I am a great believer in research and believe that the possibilities of this country are great if properly handled, and I fully agree with you that the method you suggest for promoting research in this country is far preferable to that of a large central research organization. Such a plan will utilize at once the equipment available. It would attract in the simplest way men who otherwise never spend time in investigation."

Prof. T. W. Richards, of Wolcott Gibbs Memorial Laboratory, Harvard University: "It seems to me that the Newlands Bill will undoubtedly help in drawing attention to the importance of research, and in helping also to discover adequate men."

O. H. Tittman, Chief of U. S. Coast and Geodetic Survey: "One feature of the bill commends itself especially to me, and that is the creation of many centers of interest and usefulness rather than that of a single centralized agency for experimental research. The necessary coordination can be provided by a central administrative office."

Prof. Chas. E. Locke, of Massachusetts Institute of Technology: "In the mining department, I believe that we are all in favor of the bill, our idea being that an allowance for research, though small in amount, is better than nothing. We have always carried on more or less research in the department, and for years Professor

Richards had private assistants who have carried out the experiments which have resulted in Professor Richards' discoveries and improvements, especially along ore-dressing lines. In addition to pure theoretical research, these assistants have done a great deal in solving commercial problems which are coming to us at frequent intervals. Fortunately Professor Richards has felt able to carry the financial burden of this research work, but all of us are not in that position and therefore appreciating the value of such work, would welcome any aid financially toward keeping it up."

Dr. E. P. Hyde, of Nela Research Laboratory: "It has been my judgment for a number of years that every effort should be made to develop in the United States research in both pure and industrial science and to foster a closer relationship between these and engineering, and I have felt that the present conflict in Europe has at the same time emphasized the importance of this work, and laid upon the United States the responsibility of assuming the leadership in it."

Dr. Louis Bell, of Boston, Mass.: "I heartily approve of the project as being about the most suitable thing in the way of aid to ultimate industrial development that our country has yet done. The annual appropriations of various technical departments of the Government are large, but I do not think they produce results entirely commensurate with the expenditure because they are too closely centralized and cannot make available the wide variety of talents which can be reached by the Newlands Bill."

Dr. P. G. Nutting, President of the Association for the Advancement of Applied Optics: "The Newlands Bill has my hearty endorsement for a number of reasons.

1. It is, in my opinion, the most *rational* plan for stimulating and promoting research yet proposed.

2. It is likely to produce greater *practical* results than any other scheme yet advised.

3. It is a logical extension of the government-aided agricultural research, already long past the trial stage and of proven worth.

4. It will serve the *varied interests* of the different sections of the country far better than a single central laboratory.

5. It is likely to draw fertile-minded *investigators* in far greater numbers and in far greater variety of race and training than a single federal institution. This I consider the strongest argument in its favor.

6. The contemplated distribution of laboratories will provide more *intimate relations* between research and the interests most likely to profit by it. This will lead to a better choice of research problems and greater activity in investigating them."

Prof. Henry S. Jacoby, of Cornell University: "The results which have been secured by the Engineering Experiment Station at the University of Illinois, supported by the State, show how fruitful may be such a station associated with a university."

"It is hardly possible to overestimate the aid rendered by that station in the development of a rational basis for the design of reinforced concrete since this new material of construction was introduced in the country. This is but one of many subjects investigated by that station, whose good work is recognized by engineers in other countries, as well as in our own."

C. F. Burgess, Chemical Engineer, Madison, Wis.: "In considering my past experience as a teacher, I can say that there is no doubt that research work can be greatly stimulated by having available certain funds which are to be devoted exclusively to such work."

"I applied a number of years ago for a grant from the Carnegie Institution and \$2,500 a year was made avail-

able for research on electrolytic iron and iron alloys. I can show that through this expenditure, over a period of five years, not only were results of practical importance secured, but what is even more important, a number of men were developed as investigators. If it had not been for this fund it is possible that Mr. James Aston who is now carrying on important research work for the Bureau of Mines, might still be engaged in foundry practice.

"Among other men who received part of their training and encouragement in research work through this fund are Dr. O. P. Watts, J. H. Thickens, and O. L. Kowalke, all of whom are now high grade research men.

"There are a great many college men now engaged in technical and purely routine work in industrial lines who would be attracted back to the universities for research work if such funds were available, men who cannot afford to give up their income completely and men who can quickly develop into competent investigators."

Prof. J. H. Long, Northwestern University Medical School: "I have for a long time felt that we need in this country some more tangible stimulus to beginners in research work than we at present possess; the plan of the Newlands Bill may help in the solution of the difficulty."

Program of Cleveland Meeting, American Institute of Chemical Engineers

The eighth semi-annual meeting of the American Institute of Chemical Engineers will be held at Cleveland, Ohio, from Wednesday, June 14, to Saturday, June 17, 1916. Headquarters will be at the Hotel Statler. Meetings will be held at the Hotel Statler and at the University Club, including a joint meeting with the Cleveland section of the American Chemical Society.

On Wednesday morning a meeting will be held at Hotel Statler with the following program:

Address of welcome, by Ralph L. Fuller, president of Cleveland Chamber of Commerce.

The Production of the Rarer Metals. By Joseph W. Richards.

The Utilization of American Clays. By Arthur C. Watts.

The Effect of Storage on Mixed Paints. By E. E. Ware and R. E. Christman.

At the Wednesday evening meeting at the University Club, the following papers will be read:

Recent Developments in the Production of Nitro-cellulose. By Dr. Edward C. Worden.

Nitric Acid Sofistication, a Serious Production Menace. By James R. Withrow.

On Thursday afternoon there will be a lecture on "Sound" by Dr. Daton C. Miller, of the Case School of Applied Science, at the Students' Club of Case School.

On Friday afternoon the following papers will be read:

The Cleveland Sewage Disposal Plant. By R. Winslow Pratt.

The Purification of Sewage by Aeration in the Presence of Activated Sludge. II. By Edward Bartow.

On Friday evening a joint meeting will be held with the Cleveland Section of the American Chemical Society at which the following papers will be read:

Water Powers of the United States. By Herman Stabler, U. S. Geological Survey.

Acid-Resisting Alloys. By W. C. Carnell.

Excursions will be made on Wednesday afternoon to the Central Furnaces, the Semet-Solvay by-product coke-oven plant of the Cleveland Furnace Company, and to the American Steel & Wire Company. On Thursday morning the ore docks of the Pennsylvania Railway

Company, the Cleveland filtration plant, and the works of the National Carbon Company, will be visited. On Friday morning a visit will be made to the National Lamp Works of the General Electric Company, and on Saturday morning to the works of the Goodrich Rubber Company.

The social features include a smoker and entertainment on Wednesday evening after the technical session; a complimentary luncheon on Thursday noon, with address of welcome by Charles S. Howe, president of Case School of Applied Science; a subscription dinner on Thursday evening at Hotel Statler; and a complimentary luncheon by the Grasselli Chemical Company at the Country Club, Friday noon.

Dr. George D. Rosengarten is president and Dr. John C. Olsen, Cooper Union, New York City, is secretary of the Institute.

The Western Metallurgical Field

Zinc and Copper Production in 1915

Official figures on the production of spelter and copper in the United States for 1915 have been published by the U. S. Geological Survey. The report on spelter contains a graphic representation of the average prices per pound at St. Louis and London, the average base price of 60 per cent zinc concentrates at Joplin, and the weekly production of zinc concentrates in the Joplin district. The price of the metal at St. Louis reached its maximum on June 12, 1915, when it averaged slightly over \$0.25. Another high point was reached on Nov. 27, at \$0.22. The high average price for Joplin concentrates was \$130 per ton on June 12. The production of primary spelter in 1915 amounted to 489,519 tons of 2000 lb., with a value of \$121,401,000 based on the average selling price. This was an increase of 39 per cent in production and 237 per cent in value as compared with 1914. Consumption of primary spelter in the United States increased 22 per cent as compared with 1914. The list of active zinc smelters in the United States shows 156,568 retorts in operation, with 49,612 to be added in 1916, which will make a total of 206,180. Ten electrolytic zinc plants are listed, indicating the remarkable impetus given to this branch of zinc metallurgy during the year. The total capacity of all spelter plants in the country is estimated at 885,000 tons annually. The output of electrolytic zinc for 1915 is given as 252 tons, but the estimate for the end of 1916 is at the rate of 60,000 tons per annum. The future of the industry indicates that this country will be producing spelter at the rate of about 900,000 tons per annum, including secondary metal, which is about three times domestic consumption. This suggests that at the close of the war some of our zinc plants must inevitably close unless in the meantime arrangements are made to smelt practically the entire Australian production in this country. In that event smelters situated on the Atlantic seaboard with adjacent markets for acid will have an advantage over inland smelters.

The smelter production of primary copper in 1915 amounted to 1,388,000,000 lb., an increase of 21 per cent over that of 1914. The total value of the 1915 production, at an average price of 17.5 cents per pound, was \$242,900,000, compared with \$152,900,000 for 1914. The principal copper-producing states, arranged in order of production, rank as follows: Arizona, 432,467,690 lb.; Montana, 268,263,040; Michigan, 238,956,410; Utah, 175,177,695; Alaska, 70,695,286; Nevada, 67,757,322; New Mexico, 62,817,234. The total production of new refined copper in 1915 was 1,634,000,000 lb., an increase of 100,000,000 lb. over 1914. Production of secondary copper amounted to 392,274,000 lb. The total contri-

bution of the United States to the world's supply of copper in 1915 is given as 2,026,000,000 lb. The apparent consumption of new refined copper in this country in 1915 was about 1,043,000,000 lb., compared with 620,445,373 lb. in 1914.

Company Reports

The Calumet & Arizona Mining Co. produced in 1915 65,268,910 lb. copper, 1,381,078 oz. silver and 35,264 oz. gold. Income amounted to \$11,683,724, and expenditures totalled \$6,225,595, leaving a net income of \$5,458,129. Dividends amounted to \$2,006,557. An interesting part of the report refers to the leaching and electrolytic plant of the New Cornelia Copper Co. A 40-ton experimental leaching plant was operated during the year, treating 291 charges. Results on charges 91-291 were as follows:

Average head, copper.....	1.337%
Average tailing, copper.....	0.256%
Average extraction	80.600%
Average pounds per kw. hr.....	0.958

On the basis of these tests an appropriation of \$4,200,000 was made for a permanent plant, which when completed will yield copper at the rate of 36,000,000 lb. per annum. The ore will be crushed to $\frac{1}{4}$ in. and leached in eleven lead-lined vats, each 88 ft. square by 15 ft. deep inside, having a capacity of 5000 tons each. Each vat will have its pumping system for circulating solution at the rate of about 8000 gal. per minute. An excavator of the Hulett type will be provided for discharging the vats after the ore is leached. The neutral solution from the leaching plant will be pumped to sulphur dioxide absorption towers for the reduction of ferric iron before electrolysis. The acid solution after electrolysis will be returned to the leaching plant. The tank house will contain 152 lead-lined electrolytic tanks about 30 ft. long, 4 ft. wide and 5 ft. deep. It is estimated that the plant will be ready for operation about July 1, 1917.

The consolidated earnings statement of the United States Smelting, Refining & Mining Co. for 1915 shows net earnings of \$6,592,324 which, with the undistributed surplus from the previous year, gives a total of \$11,107,916. Dividends were paid amounting to \$1,965,561; additional reserves for depreciation, \$888,900; undistributed surplus, \$8,253,455. Metal production was as follows: Copper, 26,923,674 lb.; lead, 87,102,179 lb.; zinc, 34,105,471 lb.; silver, 12,071,863 oz.; gold, 196,481 oz. The company's subsidiaries are: United States Smelting, owning zinc and lead mines and smelters in Utah and Kansas; Centennial-Eureka Mining Co., Utah; Mammoth Copper Mining Co., California; Gold Road Mines Co., Arizona; Needles Mining & Smelting Co., Arizona; Richmond-Eureka Mining Co., Utah; Real del Monte y Pachuca Mines in Mexico. Owing to disturbances in Mexico the latter properties were operated only from 50 per cent to 80 per cent of their capacity.

The annual report of the Consolidated Arizona Smelting Co. for 1915 shows a general improvement in the condition of the company's mines and reduction plants. A suit brought by Charles S. Hinchman to impress a lien of \$900,000 upon the company's property was decided favorably to the company in the Circuit Court of Appeals. Ore reserves in the Bluebell mine are given as 235,000 tons containing \$1.50 in gold and silver and 3.5 per cent copper; in the De Soto mine, 65,000 tons of the same gold and silver value as in the Bluebell, and with 3.75 per cent copper. The concentrating mill handled 81,544 tons of ore and old tailings and made an average recovery of 88.6 per cent of the copper, 62.5 per cent of the gold and 70.5 per cent of the silver. The grade of feed was 2.83 per cent copper, the ore averag-

ing 2.88 per cent and the tailings 2.09 per cent. Ratio of concentration, 4.1:1; grade of concentrate, 10.27 per cent copper. The cost of milling, including flotation royalty, was \$1.20 per ton, compared with \$1.82 and \$2.09 in 1914 and 1913, respectively. No flotation royalty was paid in 1913. Additions to the crushing and milling plant will be made to increase capacity from 240 tons to 500 tons per day. The smelter cost of receiving, crushing, sampling, handling, roasting and smelting to matte was \$3.34 per ton, as compared with \$5.55 in 1914. Cost of converting matte to blister copper was \$0.0046 per pound of copper converted. In 1914 this cost was \$0.0058, and in 1913, \$0.0137. The full effect of improvements and economies on the cost of producing copper will be apparent only during 1916, but with improved conditions the company expects to increase its output and decrease cost. Net profit for 1915 was \$194,943, without considering depreciation.

The earnings of the American Smelting & Refining Co. for 1915 amounted to \$16,242,420, an increase of \$5,430,505 over 1914. The following appropriations from earnings were made: For depreciation, \$1,839,686; employees' bonuses, \$445,000; pension fund, \$100,000; welfare work, \$250,000. Dividend payments amounted to \$8,002,924. The surplus was \$5,050,380. The company's properties in Mexico were, on the whole, unprofitable and unproductive. In addition to mining properties purchased during the year the company constructed a tin smelting plant at Perth Amboy, zinc smelting plants at Salt Lake City and Sand Springs, Okla., and a new copper refinery at Tacoma. The company extended its welfare work for employees; pensioned forty-eight old or disabled employees during the year, and has a pension fund of \$620,420.

The Copper Range Company, Michigan, earned a net income of \$3,564,762 in 1915, and paid dividends of \$1,182,003, leaving a balance to working capital of \$2,382,759. The total copper production was 37,035,642 lb., at an average cost of 8.06 cents per pound. The average price received was 17.4 cents. Rock stamped totalled 1,651,870 tons, containing an average of 32.5 lb. copper per ton.

The Daily-Judge Mining Co., Utah, had a profitable year, according to the annual report for 1915. The increase in profits was due to the higher price prevailing for lead and zinc as well as to increased ore production. The excess of receipts over disbursements amounted to \$238,753, and the balance carried to surplus was \$678,907. Dividend payments amounted to \$300,000. Ore production was 5809 tons of shipping ore and 63,935 tons of concentrating ore. The average grade and value per ton of ore and concentrates produced is given in the following table:

	Oz. Silver	Oz. Gold	Per Cent Lead	Per Cent Copper	Per Cent Zinc	Per Cent Iron	Per Cent For Sale
Crude	30.32	0.034	17.73	1.86	10.82	7.67	\$23.93
Lead conc. 31.72	0.03	38.57	1.18	9.93	15.01	38.26	
Zinc conc. 17.41	0.015	3.77	...	44.46	6.08	68.08	

The constituent companies of Phelps, Dodge & Co. produced during 1915 a total of 140,478,003 lb. copper, an increase of 8,815,679 over 1914. This large production was accomplished in spite of labor strikes that closed the Detroit mines from September to the close of the year. The Nacozari plant was closed for 135 days, due to troubles in Mexico. The balance sheet shows earnings of \$10,981,512 and a surplus of \$8,337,864. Dividends totalled 20 per cent, or \$9,000,000. At the Burro Mountain property the company is erecting a large concentrating mill, one 500-ton section of which may be in operation at the present time. The milling system has been developed as the result of experimenting with over 10,000 tons of ore of various types.

The Roitsheim-Remy Continuous Zinc Distillation Process

BY M. LIEBIG

Smelter Superintendent in Godesberg

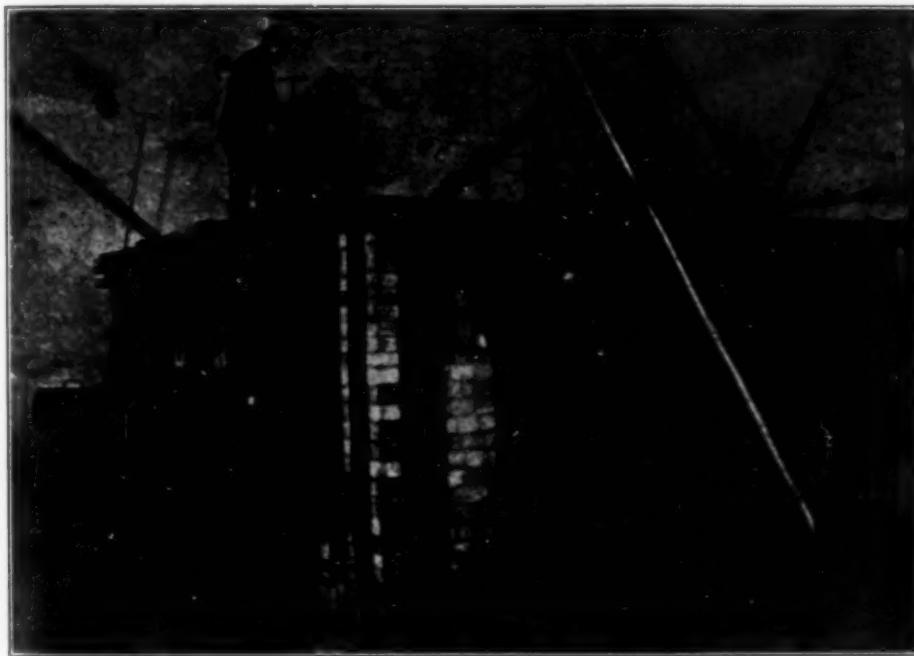
TRANSLATED BY OLIVER C. RALSTON

From *Metall und Erz*, 13, 143-156 (March 22, 1916).

At the autumn meeting of the Gesellschaft Deutscher Metallhütten und Bergleute (German Metallurgical and Mining Society) in 1913, I reviewed a series of proposed and tested processes for the improvement of the smelting of zinc in vessels heated from the outside (*Metall und Erz*, 1914, Heft 3) and mentioned the process of Roitsheim and Remy for the distillation of zinc in vertical retorts.

This interesting process has since been tested for over a year in the Hamborn zinc smelter of the Aktiengesellschaft für Zinkindustrie, formerly Wilhelm Grillo, in Oberhausen.

I am now in a position to comment further on this



ROITSHEIM-REMY CONTINUOUS ZINC FURNACE

invention and its practical applicability, as well as to call attention to the fact that it promises to revolutionize zinc smelting.

The inventors carried out their first tests in Langerwehe (Rheinland), in a test furnace containing six vertical retorts and demonstrated the possibility of smelting zinc by this process. On the strength of these tests an improved test plant was installed in the Hamborn smelter at Oberhausen in 1912. This furnace was built with twelve muffles, each capable of producing 25 kg. (55 lb.) of zinc per 24 hours. The residues were very low in zinc and even ores which slagged easily yielded up their zinc content without trouble. This furnace improved on the work of the Langerwehe furnace and yielded satisfactory zinc.

On that account I was able to state at the above-mentioned meeting in Berlin on Nov. 23, 1913, that I regarded the question of distillation of zinc ores in vertical retorts as solved.

The world-stirring events of the following year, which called all forces to the defence of the Fatherland, promised to hinder this work, but thanks to the fearless faith of the Aktiengesellschaft für Zinkindustrie,

and of the inventors, and thanks to their eager cooperation, it was possible to build another test furnace in 1915 which was run in large-scale production of zinc, giving every opportunity to compare the new process with the standard old practice. Fig. 1 gives an idea of this 10-muffle installation, showing one side of the furnace and the top.

The advantages of this new process over the regular process are: first, better labor conditions; second, less dependence on labor; and third, greater ease of operation.

Every zinc smelter has been concerned in recent years with the ever-increasing gravity of the labor question. It is easy to understand the attitude of the zinc furnace man who would rather enter some other industry which is technically up to date than remain in the zinc industry, which is at a standstill, as far as technical development has been and which calls for so much physical exertion. It was this problem which the inventors sought to solve. They accepted the standpoint that the reduction of zinc oxide has been successful only in retorts heated from the outside. They merely sought by changing the arrangement of the apparatus to do away with the excessive amount of heavy manual labor.

The inventors have succeeded. By the use of suitable apparatus they have not only reduced the manual labor, but have reduced the number of laborers necessary in the zinc melter by 40 per cent. Further we find that a like diminution of the work in the muffle factory is a direct result of this invention. Not only should the news that only 60 per cent of the former labor force will be needed bring joy to the hearts of the smelter men, but also the fact that unskilled labor is all that is required for most of the work. The work is easy to learn, does not tax the strength, and takes on more

the character of watching machinery. The discharging and loading periods which formerly subjected the laborers to intense heat were also done away with and now most of this heat is conserved.

Besides the solution of the vexing labor problem it has also been found that the work can be much better and is more easily carried out. It is found that the operation costs, outside of the labor, are also much lower, thanks to the configuration of the retorts. The question of discharging and loading machines has been much in the foreground, of late, and the presses for the present type of condensers are very complicated compared to the simple presses for making the muffles.

The upright retorts have solved both problems. Roitsheim and Remy obtain continuous reduction by feeding preheated ore charge into the top of the retort and discharging a dezinced residue mechanically from the bottom of the retort in a cool condition. The retort is open at top and bottom, but sealed from the atmosphere above by the fresh charge and below by the "ashes." The condenser is perpendicular to the muffle and is in a suitable heated niche.

This new apparatus is so simple that the use of un-

skilled labor is allowable. It has been patented by the inventors in most of the important countries. Above, the muffle has a continuation for receiving the ore charge and for preheating it. Below the muffle rests on a cast-iron cooling chamber in which the extracted residues are cooled to the point where no more fumes are evolved before they are discharged by a mechanically driven discharge. In a niche cut in the wall and connected to the muffle through a hole at the proper height is the condenser, which is heated to the proper temperature for condensation of good zinc. This clay condenser is shaped like the old muffles of the three-tier Rhenish zinc furnace. It can be made in the old muffle presses so that these old presses need not be discarded in adopting the new process. So the inventors have found a simple solution of the problem of disposing of the zinc vapor. In the front end of the condenser is set the tube which leads into the prolong which catches the zinc dust. The prolong is divided by a partition so that the gases are discharged near the furnace into an opening which leads to the stack. At this opening the gases are ignited and the color of this carbon monoxide flame serves, as of old, to indicate whether there is any uncondensed zinc present, and is used as a control on the operations of the furnace.

The heating of the muffles takes place in a combustion space which is divided in the middle by a checker-work wall, and usually regenerative gas firing, like that in the best modern ovens, is used. The test furnace was built one-fourth of the proposed full size. The full-size furnace will have forty retorts, twenty on each side of the middle wall. The comparatively small combustion space, the position of the burners and the communication openings in the central wall allow of an easy regulation of the performance of the furnace, and by the use of slides actuated from the outside the supply of gases can be regulated for each muffle.

The reduction takes place quickly and quietly. The whole performance of the furnace is dependent on the muffles being kept filled with ore, and their upward extensions can easily be tended by one man. An electrically driven discharge, which is set in motion by the laborer on top of the furnace, removes a certain portion of the charge from time to time at the bottom, and with the removal of this residue the contents of the muffle must sink. In case it does not sink down the workman on top loosens it with an iron rod. This is all the manual labor which is connected with the reduction. Hence the activity of the furnace man is restricted largely to the superintendence of the machinery.

The tapping of the zinc, which is necessary only once in twenty-four hours, is easily done on account of the position of the tap hole, and the zinc runs into a portable pot. This is fairly free of lead, and the use of a mixing kettle is not necessary, as the steady reduction temperature yields a zinc which does not require further refining.

The following are examples:

Ore, Per Cent	Zinc, Per Cent	Zinc Dross, Per Cent	Zinc, Per Cent
50.46 Zn	98.67 Zn	72.97 Zn	99.02 Zn
3.76 Pb	1.24 Pb	6.62 Pb	0.860 Pb
5.90 Fe	0.014 Fe	1.46 Fe	0.033 Fe
0.61 Cu	0.004 Cu	0.49 Cu	0.000 Cu
	0.077 Cd	0.42 Cd	0.042 Cd

The tapping of the zinc is best done by two special laborers, and is easily and simply done, because there is only one row of retorts on each side and they are all at the same height. On account of the regularity of the process the condensers can be emptied at a certain time every day and two men can serve three furnaces. They first take off the prolong, collect the zinc dust, and then tap the zinc in the condenser by opening the tap

hole beneath the tube for attachment of the prolong. In order to remove any slag or dross from the muffle, the tube is removed to allow entrance of the proper tool. The tube is then replaced, luted, and the prolong stuck on again. As two men serve three furnaces, or 120 retorts, their work is not excessive. They find ample time to scrape out any condensers which are filling up with accretions. During the test run it was found that hand-made condensers lasted forty-five to fifty days. If machine pressed condensers had been used they would probably have lasted much longer. With 120 condensers and a life of forty-five days only three or four of them would have to be replaced each day in the three furnaces, work occupying only three-quarters of an hour.

The extraction is better by this process than by the old one. In the old one the operations were interrupted to allow emptying the retorts and loading them with fresh charge, and hence subjected to heavier strains than in the new process. The constant temperature to which the new retorts are subjected during their whole life contributes materially to their life. The continuous charging causes far smaller losses and the uninterrupted distillation tends to form much less dross, accretions and zinc dust, and hence less zinc has to be redistilled. Further, by slowing down the rate of discharge it is possible to keep the ore in the heated zone longer and obtain lower grade tailings. In the test runs it was the rule to obtain 3 or 4 per cent Zn in the residue, although as low as 1 per cent was not uncommon, which naturally reduced the losses. Further, the residues not being discharged until they are cooled, there is not the old loss of zinc vapor. All these circumstances tend toward higher extraction and more or less toward a higher grade product. If the residue is assumed to contain on an average 3 to 4 per cent of zinc, the capacity of muffles for a charge of 47-50 per cent Zn content can easily be 45 kg. (99 lb.) of zinc, and with the addition of some zinc dross the capacity could be raised to 50-55 kg. (110-121 lb.). When smelting zinc oxide or only zinc dross, a capacity of 65-70 kg. is easily possible (143-154 lb.). Hence a forty-muffle furnace will smelt at least 1.8 metric tons (two short tons) of zinc daily.

The life of the retorts in the test plant was seventy to 80 days for hand-made muffles made of ordinary muffle clay. It is safe to assume that the machine-pressed muffles ought to last ninety days, and their shape is such that it does not require a complicated press. This makes it necessary to replace only five or six muffles per day in a single installation of twelve furnaces (480 retorts). Some manual labor would be involved in loosening and removing the old retorts and introducing new ones, but since the individual control of the muffles makes it possible to replace muffles without interfering with the operation of the furnace, the furnace men need not do this work, and special men can be detailed to do nothing but the replacing of muffles. An electrically driven overhead crane is necessary for carrying on this replacing operation. The replacing of five or six muffles every day can be done by seven laborers, outside of the crane runner, in about six hours. Only about half of the time of the crane is required, and the rest of the time can be occupied with other duties, such as hauling ore. It would also seem that with experience the age of retorts and condensers could be lengthened. Slagging of the muffles, by the very nature of the process, is rendered less likely and breaking of both muffles and condensers by temperature changes is also eliminated.

The removal of the residue takes place by a mechanical discharge. Each retort is provided with one. Each is set in motion by levers which extend up to the top

of the furnace, and is actually in motion only a few minutes each hour. The material discharged is usually fine grained and cooled. In the test plant, these zinc ashes discharge into tram cars in the tunnel underneath, but in larger installations the use of a conveyor belt would be better, or the material could fall into a sluice. The concentration of zinc in the ashes by gravity or other methods is easier and cheaper in this process, because crushing is not necessary, as a rule. The saving of the excess coal from these residues amounts to as much as 45 per cent of the total coal used for reduction. The consumption of cooling water is quite low if it is cooled and reused, so that only evaporation and leaks have to be made up. The mechanical discharge and ash coolers in the test work showed no visible wear after one year's work, so that they could be expected to last for several years.

Repairs to the remainder of the furnace are very small. An arch is not used. The walls of the condenser niches are strong and subjected to no abrasion. The gas and air channels are under the condenser niches and parallel to the row of muffles. Hence stoppages due to slagging or crumbling, both in these channels and in the holes through the central dividing wall, are very unlikely. The side walls form a strong block of masonry, which is heated on only one side and only the central dividing wall is subjected to heat from both sides. Complete renewal of the furnace work is easy of accomplishment, and an interruption of the work of only fourteen days results, including time to cool down and fire up again. The individual gas burners allow cutting off the supply to a single compartment long enough to make minor repairs and thus increase the length of life of the furnace setting. On account of the fact that the regenerators need to be overhauled every three years, greater improvement along this line is not necessary.

The spacing of the furnaces is also materially changed. In the old practice, with much radiant heat, it was necessary to leave a great deal of space between the furnaces, but with the new furnaces this working space between the center lines of two adjoining furnaces is 11.4 meters (37 ft.), so that in a battery of twelve furnaces, including furnaces for tempering the retorts, the total length of the building should be about 150 meters (492 ft.). The width of the room, from the middle of the columns to the middle of the columns is 25.5 meters (83.5 ft.), so that in front of the furnaces is a space of 6 meters (21 ft.), and behind is a space of 2 meters (6.5 ft.), while the furnace is 14.5 meters long (47 ft.). On account of the necessity of a crane for placing the retorts the height of the room to the eaves should be about 15 meters (49 ft.). For the tempering of the retorts and condensers such a plant would need two pit furnaces with movable covers and fired by generator gas. The transportation of the ore is by means of the crane, which is used for fuel for the gas producers as well as by use of the retort crane. At the end of each furnace is the ore bin, which feeds a tram having two bottom discharges and which runs along over the two rows of retorts in the furnace.

The arrangement of the gas producers is also changed. Where formerly it was necessary to have a separate gas producer for each furnace on account of the intermittent firing, the new continuous furnaces can draw from one large common source of gas. More economical operation and better superintendence are possible, and conditions are now right for the recovery of the by-products from the gasification of the coal.

In practice three furnaces may be connected to a gas main fed by two big producers, which are

housed in a room with all the gas pipes necessary, and next to the furnace room. This continuous operation of the producers should result in economies of fuel and labor, but this point was not tested in the experimental plant as the amount of gas consumed in the small furnace was only one-fourth of the output of one of the ordinary producers.

That the results of this test are highly encouraging is beyond all doubt. The number of retorts and condensers for a given output of zinc or for a given amount of ore smelted is reduced to one-third of the former figures, and the number of them used up in a given time was reduced to one-eighth of the former number of retorts and one-twelfth of the condensers, while the refractory materials consumed were only about half to one-sixth of the former figure.

What other advantages may be possessed by the new process, especially with regards to costs of operation, can be seen by the following comparison of the standard Rhenish three-tier type of zinc furnace with the Roitsheim-Remy system.

For purposes of comparison there have been taken a Rhenish smelter with twelve regenerative furnaces, each of 240 muffles, and a Roitsheim-Remy smelter with twenty-four furnaces of forty vertical muffles. If the life of a Rhenish furnace is taken as three years, it can be seen that during each year four of the furnaces are out of commission for two months during rebuilding. With a duty of 3.8 tons for each muffle, we have 4380 (less 250 furnace days) $\times 3.8$ = roughly 15,700 tons of zinc yearly from the Rhenish plant, or a daily average of 43 metric tons of zinc, corresponding to the daily smelting of 95 tons of ore containing 51.5 per cent Zn and with 88 per cent extraction. The new system of the dimensions mentioned above will have about the same capacity. Taking the life of the new furnace as six years, and remembering that it is out of commission for reconstruction for only a short time (four furnaces out for fifteen days every year), the annual production will be 8760, less 60 furnace days $\times 1.8$ = about 15,666 tons. The danger of closing the plant on account of labor difficulties is much less with the new plant, for the reason that 40 per cent less labor is required, and of these only a few need be skilled laborers. The simplicity of operation and the small exertion required of the men, as well as the shorter hours which many of them will be allowed to work, will insure much steadier operation. In well-regulated operation extra laborers will not be necessary. A comparison of labor requirements is given in Table I (page 628).

The average wage under German conditions is 5.50 marks in both cases, although the Roitsheim-Remy smelter would be much the more desirable to work on account of the easier and better labor.

The daily labor expense for the production of 43 metric tons of zinc (or 48.2 short tons) will be:

Old process, $325 \times 5.50 = 1,787.50$ marks (\$426).

New process, $194 \times 5.50 = 1,067.00$ marks (\$254), or 41.57 marks and 24.82 marks per metric ton of spelter (\$8.85 and \$5.27 per short ton of spelter respectively).

The saving of the new over the old process is hence seen to be per ton (metric) of zinc, 16.75 marks, or 40.3 per cent (per short ton, \$3.58).

A further important saving is in the lessened consumption of refractories. The life of muffles in the old method was twenty-eight days, while in the new process it is ninety days, and consequently the corresponding amount of breakage in tempering is greatly diminished — 100 retorts per day in the old process and twelve in the new, because there are 2716 (11.32×240) and 954 (23.84×40) retorts, respectively. The consumption

TABLE I—COMPARISON OF LABOR REQUIREMENTS

Figures taken from practice of Corresponding labor requirements of the Roitsheim-Remy representative Rhenish smelter.

Two series of six furnaces	Two series of 12 furnaces
12 smeltermen per furnace..	144
2 zinc pullers per furnace..	24
2 stokers per furnace..	24
2 repair men per furnace..	24
2 foremen per room..	24
1 general foreman..	1
6 ash trammers..	6
6 ash trammers for producers..	6
6 ore trammers..	6
6 coal trammers..	6
1 muffle trammer..	1
1 prolong maker..	1
3 toolsmiths..	3
6 extra laborers..	6
10 brick masons..	10
5 hod carriers..	5
30 roustabouts..	30
Total	301
	Total
	180

Therefore there are 121 men less, or 40.2 per cent decrease.

IN THE RETORT FACTORY

Muffle pressers	3	Pressing of muffles, etc..	3
Muffle molders	2	Pug mill, etc., workmen..	2
Brickmaker	1	Molder	2
Pug mill, etc..	1	Fireman	1
Condenser press	4	Other workmen	5
Condenser molder	2	Foreman	1
Firemen	2	Total	14
Foreman	1		
Muffle trammer and glazer..	2		
Condenser and brick trammer	2		
Total	24		

Therefore there are 10 less men or a decrease of 41.7 per cent.

Grand total..... 325 Grand total..... 194

Hence the total saving in labor is 131 men or 40.3 per cent.

of condensers, calculated in the same way, with life of ten days and 45 days respectively in the two processes, is 320 and twenty-two condensers daily. The amount of material used for luting and other purposes is diminished correspondingly.

There are used in the muffle factory the following weights of refractory material:

In Old Process	In Roitsheim-Remy Process.
100 muffles of 95 kg..	9500 kg.
Bricks	3000
320 condensers and tubes	4800
Lute, etc.	1200
Mortar	300
	18,800 kg.
5% broken and worked over	940
Total	19,740 kg.
	5% broken and returned
	500
	Total
	10,834 kg.

Hence the saving of refractory materials would be 8900 kg. daily, or about 45 per cent.

Aside from the cost of preparing them these products cost about 20 marks (\$4.77) per metric ton, and hence the value of the refractory materials saved is $8.9 \times 20 = 178$ marks (\$42.40) on 43 metric tons of zinc, or 4.14 marks per metric ton of zinc distilled (88 cents per short ton). This saving amounts in one year to 3250 metric tons of refractories or 50,000 marks (\$11,900) in working capital, which referred to 1 ton of zinc at a rate of interest of 5 per cent, amounts to 0.16 mark (3.4 cents per short ton).

This diminished consumption of refractories causes a corresponding saving in fuel in the drying room and in the tempering furnaces.

In the drying room only a third of the former 1000 kg. of coke or 330 kg. are used, causing a saving of 670 kg. at 18 marks per metric ton (\$3.83 per short ton) of 12.06 marks (\$2.87). In the old process the tempering of 100 retorts required three tempering furnaces with a consumption of coal of 2400 kg. per day, while twelve of the present muffles, which take up the room of forty-eight of the old retorts, require two furnaces with a consumption of 1200 kg. of coal (1.345 short tons). The saving in coal is hence 1200×14.00

marks = 16.80 marks. For 1 ton of zinc these two items amount to $28.86/43 = 0.67$ marks (14.2 cents per short ton).

The total savings on the refractories amount to 4.27 marks per metric ton of zinc (\$1.06 per short ton). The saving in tools and machine work is significant.

In Old Process	In New Process
100-120 tools per furnace with wt. of 150 kg. at 50 marks $\times 24 \times 12 = 6,000$ marks.	30 tools per furnace with wt. of 150 kg. at 50 marks $\times 24 = 1,200$ M. for 24 furnaces.
Repaired and renewed three times annually, 18,000 marks in one year.	The tools consist for the most part of round iron bars (16 mm.) used from time to time to shake down ore that is sticking up in the muffles. They last two years.
18,000/15,700 tons = 1.15 marks per ton of zinc.	0.5 \times 1,200 = 600 marks per year, or 0.04 marks per metric ton zinc.
240 prolongs for each 12 furnaces at 3 marks each, 8,600 marks.	40 prolongs for each of 24 furnaces at 4 marks each = 3,840 M. These are handled very carefully and in the test work showed that a life of two years is certain. Hence 1,920 marks per year, or 0.12 marks per metric ton zinc.
These have to be replaced twice per year, or 17,280 marks, or 1.10 marks per metric ton zinc.	

The saving from these items is 2.09 marks per metric ton of zinc (or 44.5 cents per short ton).

The removal of cooled ashes will make it easier on the tram cars and trammers when these are used. There will also be a saving in the shovels used. There is doubtless a like saving in the coal for firing the retorts, but as the test plant has never been stopped the exact amount has not been estimated.

The smaller force of laborers will cause further savings. Fewer wash houses and boarding houses, as well as dwellings for the workmen will be necessary, and a corresponding saving in light, water, soap, etc. The increased safety of the work and its added comfort, which means smaller insurance rates, is also of importance.

We are certainly safe in estimating that all these minor savings will amount in all to 3 marks per metric ton of zinc (64.0 cents per short ton), because a saving in the heating fuel of only 5 per cent could amount to 1.85 marks per ton of zinc (39.3 cents per short ton), and the other 1.15 marks corresponds to yearly earnings of 18,000 marks (\$4,290).

Against all these economies we have to consider a greater use of power in the driving of the discharging machines and for pumping the cooling water, as well as for driving the muffle crane. The latter works four hours daily in setting muffles with a cost of 2.60 marks (62 cents). Each discharge apparatus is in commission for about two hours. For the 950 discharging machines the power cost will amount to 10 marks (\$2.38), and the water pumps use power valued at 25 marks (\$5.95). These figures total 37.60 marks (\$8.96), or 0.88 marks per metric ton of zinc (18.7 cents per short ton). Summing up the economies:

1. Saving in labor, 40.3%, or per metric ton	16.75 M. (or \$3.56 /sh. ton)
2. Refractories, etc.	4.97 1.058
3. Tools, etc.	2.09 .444
4. Heating coal and general costs....	2.00 .638
Total	26.81 M. (or \$5.70)
Deducting special power costs.....	.88 .18

Per metric ton of zinc..... 25.93 M. (or \$5.52 /sh. ton)

Applying this to the saving in the cost of production of a year's output, the new process makes a saving in the production of 15,700 metric tons of zinc of 407,000 marks (17,600 short tons and \$97,000).

Besides these mere advantages in economy we have other important things to consider, such as the increased extraction. As the result of depending less on the care and skill of workmen, there are smaller mechanical losses of ore and metal. The furnaces, as now designed, have much less dead space and are easier to regulate. They are much easier to superintend, and

finally, due to the method of handling the residue, the furnace room is free of fumes, which should mean the saving of a considerable amount of zinc. With zinc worth 450 marks per ton (\$95.75 per short ton, or 4.78 cents per pound), the increase in extraction of 1 per cent means a saving of 80,000 marks in one year (\$19,020). Just how far any single smelter can go in attaining all of these economies depends on the care with which all the various factors are investigated and the designs made accordingly. Such factors are suitable location, the labor conditions, the cost of raw refractories and the possibility of getting the ore into the furnaces with as little stocking as possible. The saving of capital due to good design can be considerable.

The cost of construction of a modern Rhenish furnace with regenerators and 240 muffles, including the equipment for disposing of the combustion gases, but not the gas producers, under Rhenish conditions is about 60,000 marks (\$14,300). A Roitsheim-Remy furnace with forty muffles will cost, at most, 30,000 marks (\$7,150). But since the Roitsheim-Remy furnace produces only one-half the zinc produced by the Rhenish furnace under discussion, the costs of installation of both systems is about the same. What makes the Roitsheim-Remy furnace expensive is the discharging machinery for the retorts. The fitting of each retort with discharging machinery will raise the costs on such a furnace 22,000 marks (\$5,480). But, as has been said above, the wear and tear on these parts is so small that their ultimate cost is negligible. Further, zinc smelters are only too anxious to substitute for the old laborious way of doing things, especially in the discharging of the ashes. Besides the mechanical loading features and the fact that the retort crane does most of the work in replacing the retorts a cheap tram is used for loading the retorts, all of which will cost 300 marks (\$71.50) for each furnace. Exclusive of the retort crane, the cost of the series of twelve furnaces is about 250,000 marks (\$59,600), and besides this two small pieces of apparatus for setting muffles, and costing 6,000 marks (\$1,428). The apparatus for catching the fume on the new furnace is extremely simple, and corresponds to the old fume catchers and ventilating systems. Mechanical power for its operation is not necessary, as the chimney affords enough draft to catch all of this, so that the new smelting rooms will be completely free of fume.

It would hence seem that the discharging machinery, etc., is going to make such a Roitsheim-Remy smelter cost in all about 300,000 to 400,000 marks (\$70,000 to \$95,000) more than the corresponding Rhenish smelter. However, the introduction of loading and discharging machinery of any kind into the latter would cost this much, and such machinery certainly would be adopted if it could be shown to be practical, and even then it would leave much to be desired. But we have to count in the saving in ground space covered, which is about half of the old system, and about the same saving in space is made in the gas-producer room, as well as a considerable saving in the number of gas producers employed. In order to afford space for the retort crane and the ore and coal crane, however, the buildings must be made somewhat higher. The increased cost due to this necessity is more than over-balanced by the savings along other lines. Some of the advantages gained from the 40 per cent reduction of labor are less number of dwellings for the workmen, the lower operating capital for all these things, the possibility of attaining full capacity quickly, and the ease of operation.

Finally, we must not forget that the Roitsheim-Remy process will have a notable influence in improving the environment and the hygiene of the workmen.

May Meeting of American Iron and Steel Institute

The tenth general meeting of the American Iron and Steel Institute was held at the Waldorf-Astoria, New York City, on May 26 and 27. The attendance was very good and the papers covered a variety of subjects of vital interest at the present time.

In his presidential address on "Public Sentiment," Judge E. H. Gary emphasized the necessity of efficient military preparedness, and urged the adoption of laws or amendments to protect American industries. He stated that a large percentage of producers will suffer if the tariff laws are not changed, and also alluded to the necessity of laws or amendments to place our merchant marine on an equality with other nations.

In a paper on "By-products Recovered in the Manufacture of Coke," W. H. Childs emphasized the need of finding outlets for the pitch produced incidental to by-product coke manufacture. The other by-products seem to have ready outlets. In a paper on electric steel, Dr. John A. Mathews said the electric furnace did not come into use to replace other processes, but rather to fill a new demand for high-grade steel. He stated that there were at present 110 furnaces built or building in this country. Other papers read were on "Rail Manufacture," by Dr. John S. Unger, and on "The Distribution of Materials in the Blast Furnace," by G. W. Vreeland. The latter paper dealt chiefly with improvements in practice brought about by the rotating top and distributor.

The annual banquet was held on Friday evening, at which addresses were made by Edward N. Hurley, vice-chairman of the Federal Trade Commission, and Jacob Lowenstein of the American Bridge Company.

The Iron and Steel Market

Some very interesting reactions are taking place within the iron and steel market, while the general position of the steel market is unchanged. The steel market has stopped advancing, as to any really noteworthy movement, while the buying has become very light. The present condition represents the culmination of a trend that has obtained for two months. The heaviest advances in steel prices were in February and March, about equally divided between the two months. April saw relatively small advances, and the advances in the fore part of May were almost inconsequential. In the past fortnight there have been no advances, except in a few descriptions of manufactured steel. Rivets, for instance, were advanced \$5 a ton to 4.25c., while nuts and bolts were advanced 5 to 10 per cent.

Generally it requires the fear of advanced prices to bring buyers of steel into the market for large tonnages. In the great buying movement just closed there was more marked than usual another element, fear that deliveries would not be obtainable at any price if buying were deferred. With nothing approaching a definite prospect that prices will advance farther, with the level already extremely high, and with buyers as a rule well covered for months to come, probably as far as they can foresee the future of their own business, it is natural and inevitable that the market should become very quiet. The business has been put on books and the task now is to fill it.

There are, however, some interesting reactions going on within the market. There was no coherence, and indeed there rarely is much in a general advance, in the respective advances in pig iron, unfinished steel and finished steel. In a general way billets usually advance fully as much per gross ton as finished steel does per

net ton, which does not seem altogether natural for on general principles the spread ought to widen somewhat as higher levels are reached, to make a logical market. Pig iron generally advances not a great deal less than unfinished or finished steel. In this movement the total advances, averaging the various commodities in groups, were about \$6 a ton in pig iron, \$26 a ton in billets and \$28 a net ton in finished steel.

For several months past the preponderating view in pig iron selling circles has been that pig iron would have a further and more marked advance, through exhaustion of pig iron stocks and completion of additional steel making capacity, it being taken for granted that all existing steel making capacity would be kept under the highest pressure for tonnage. The pig iron advance has not occurred, and there are even some evidences of weakness developing. Sales of Southern iron at cut prices, largely speculative iron, have not been uncommon and there have been occasional weaknesses in other markets.

A still more interesting reaction within the general iron and steel market has been the curious decline in billets. There are two remarkable features, that the decline occurred just as large orders for "war steel" were being booked, and that the decline is in prompt rather than forward deliveries. Prompt lots can be bought at lower prices, while forward deliveries are held at as high a figure as has ever been quoted as the market. For plates one must pay about a cent a pound more for prompt delivery than for delivery in the first quarter of next year, while billets can be obtained at about \$5 a ton less for prompt shipment than for regular deliveries over the third quarter, and deliveries in the first quarter of next year would hardly be quoted at all.

Psychology of War Orders

Why should soft steel billets decline when large orders are placed for war steel? The writer does not know, but is strongly inclined to adopt the theory that the stiffness of the billet market in recent months has been due not entirely to the mills being unable to arrange deliveries of billets, through their mills being congested, but largely to their determination to maintain capacity open for any orders for the very profitable "war steel" that might be offered. Sales of war steel in May, including forging billets for export, rolled rounds for domestic makers of shells and for export, probably totaled considerably more than half a million tons in May, but this buying probably concluded the purchases to be expected for any delivery this year. Accordingly the mills knew what they had to count upon, and felt freer to offer soft steel. Another influence presumably is the continued increase in steel making capacity.

The lower prices for billets are for prompt delivery, and represent odd lots accumulating here and there, rather than regular offerings. An assured supply for a period of months would command more, probably as high a price, as at any time. That steel, as steel, should decline at all, however, when finished products remain very strong, suggests a new alignment as to productive capacity. Last September, when the market began to show its remarkable strength, it was the common observation that the strength was simply in steel. Only in wire and merchant bars was there any pressure upon finishing mills; it was a case of finding steel to operate the finishing mills. Now it appears that the pressure is more largely upon the finishing mills, with an augmented production of ingots due to hard driving and the availability, as scrap, of large tonnages of discards occasioned by the manufacture of war steel. The new construction work now in progress looks to the completion, in the next few months, of more steel making than

steel finishing capacity, and thus there is a prospect that this trend will continue.

The future of the steel market in general appears to be well defined. Reinforced by only a very small volume of new business from month to month, and some new business must always be cropping out, the tonnage on the books of the producers will carry them at capacity operations well over the turn of the year. Little is to be expected by way of changes in prices of finished steel. Should the war last through the greater part the steel market would be put to a very severe test. A large part of its foundation at present is the fact that cheap steel is still due customers in large tonnages. All consumers are not forced to pay present prices, and in all probability all could not. Consumption would have to be curtailed. If the war lasts long enough there may have to be a readjustment in steel prices before it ends. Should the war end about the close of this year, or early next year, the event would be the signal for a general readjustment. Enough is known of the manner in which the cost of producing steel has been advancing, through labor and other conditions, to make it very probable that the steel producers will elect to have a general readjustment in costs, to prepare for such good and steady business as may come after the war. They are likely, therefore, to endeavor to maintain prices even though that should act as a decided damper upon buying, with the idea of meeting conditions with appropriate prices, after the necessary readjustments in costs have been effected through a period of a few months of partial idleness.

Pig Iron

The pig iron market has been quiet, except in spots, and has yielded slightly at some points. The Buffalo furnaces have continued their drive noted in the last report and the Buffalo market is quotably lower. Resale Southern iron has gone at cut prices from \$15, Birmingham, while furnaces have sold at this price for second half instead of demanding the premium formerly asked. Basic iron in the valleys is a shade easier, the Republic Iron & Steel Company having bought 15,000 tons at \$18, valley. It bought 15,000 tons of Bessemer at the same time at \$20.50, valley, but other sales have since been made at \$21, the price formerly quoted as the market. There are interesting possibilities in Bessemer iron. There are large requirements abroad, but ocean freights have been considerably more than the cost of the iron delivered at seaboard. There is a possibility of ocean freights declining materially, and this would undoubtedly bring out a demand that would absorb the relatively small tonnages of Bessemer iron available. We quote: No. 2 foundry iron, delivered Philadelphia, \$20.25 to \$20.75; f. o. b. furnace, Buffalo, \$18.50 to \$19; delivered Cleveland, \$19.30; f. o. b. furnace, Chicago, \$19; f. o. b. Birmingham, \$15; f. o. b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21; basic, \$18 to \$18.25; foundry, \$18.50; forge, \$18; malleable, \$18.25 to \$18.50.

Meeting of New York Section of American Chemical Society

At a meeting of the New York Section of the American Chemical Society to be held at Rumford Hall, Chemists' Club on Friday, June 9th, C. Baskerville will report for the Committee on University and Industry. Papers will be presented by George A. Burrell, of the Bureau of Mines, Pittsburgh, Pa., on experiments on the properties of various gases, and by F. E. Wright, of the Carnegie Institute, Washington, D. C., on the petrographic microscope in analysis.

Ore Flotation*

BY WILDER D. BANCROFT

When discussing the theory of ore flotation, people are apt to lay great stress upon surface tension in general and upon contact angles in particular. While this is entirely legitimate, it seems undesirable, because we cannot measure a contact angle with any accuracy and because the actual existence of a contact angle is a matter of doubt.¹ The problem of ore flotation is a very simple one or a very complex one, depending on our point of view. It has been customary to consider it as a very difficult problem, but the other attitude rather appeals to me. There is nothing strange to us in the fact that water wets glass and that mercury does not. We also know that water does not wet greasy glass readily. If one wishes to say that these facts are mysterious, I concede it willingly, because everything becomes mysterious if one follows it back far enough. All I claim is that this is no more mysterious than anything else, and that if we start with these bits of every-day knowledge as given, there are no other serious difficulties in connection with ore flotation. Ore flotation is not a unique phenomenon, it is merely a special case under the broad heading of emulsions.

If a liquid wets a solid, it is adsorbed by the solid, forming a liquid film on the surface of the latter and displacing the air film that was there. If a liquid is not adsorbed by the solid, it does not wet the solid. The formation of a liquid film over the surface of a wetted solid accounts for the experimental fact that the rise of a liquid in a capillary tube is independent of the nature of the walls of the tube. This has always seemed a very improbable state of things, and one that could be justified only by the fact that it was so. It becomes quite simple, however, the moment we consider that the rising liquid does not come in contact with the walls of the capillary tube at all. We are really dealing with the rise of liquid in a liquid tube, and it makes no difference what material is used to support the walls of the liquid tube. That this is the real explanation may be seen from the fact that concordant results are not obtained when a liquid is allowed to rise in a dry tube. To get good results it is important to immerse the tube in the liquid and then to raise the tube.

Since the wetting of a solid is a case of selective adsorption, we should expect that one liquid would wet a given solid more readily than another liquid does, and consequently that the first liquid would displace the second from contact with the solid. No systematic study of this phenomenon seems to have been made, but we know that alcohol will displace oil in contact with metal² and that water will displace kerosene in contact with quartz.³ If we shake a finely divided solid with water and a liquid which is not completely miscible with water, an oil for instance, we can distinguish three cases. The solid is wetted entirely by water, in which case it stays in the water phase and settles to the bottom of it. The solid is wetted entirely by the oil, in which case it stays in the oil phase and sinks to the bottom of it. The solid is wetted simultaneously by oil and water, in which case it passes into the interface separating the two liquids. If the oil is less dense than the water, as is usually the case, it is a little difficult to distinguish between the last two cases. If the non-aqueous liquid is denser than water, chloroform or carbon tetrachloride for instance, it is difficult to distinguish between the

first and third cases. The particles will float if the mean density of solid plus adherent oil film is less than that of the water. They may also float if the action of gravity is not sufficient to overcome the surface tension of the water and thus to pull them through the surface. The maximum weight of substances which can be floated can be calculated from the surface tension under ideal conditions. This calculation applies only when the solid passes into the upper liquid, and does not hold for the case where the solid passes into the interface.

Since we are dealing with selective adsorption, we should expect to find that certain substances would float readily, some others less well, and still others not at all, both the nature of the solid and of the liquid having an effect. This is the case experimentally. Hofmann found that lead iodide, silver iodide, mercuric iodide, mercuric sulphide, and mercuric oxide were floated by ether, butyl alcohol, benzene, kerosene, and amyl alcohol. Copper sulphide, lead sulphide and calcium carbonate were floated only partially by ether, but completely by the other liquids; while zinc sulphide and tin sulphide did not float readily in ether or butyl alcohol, and calcium sulphate was not floated by any of the liquids.

An interesting experiment, which has been done in my laboratory,⁴ is to shake copper powder or aluminium powder with kerosene and water. The metallic powder goes into the kerosene and into the interface, producing an effect of molten copper or molten aluminium, as the case may be. When the bottle is allowed to stand after having been shaken, the metallic powder in the interface creeps up the side of the bottle above the surface of the liquid, rising higher if a little alcohol has been added. I have seen an apparently coherent metallic film rise 2 or 3 in. above the surface of the upper liquid phase. If too much copper or aluminium be added, the kerosene cannot hold all of it up and a portion falls to the bottom of the flask, carrying crops of kerosene with it. If the mixture be poured out on a piece of wood, the copper spreads over the surface of the wood just as it did over the surface of the glass. This experiment illustrates the principle involved in all bronzing liquids. A bronzing liquid consists of a volatile liquid which will hold up the metal, and some substance which will keep the metallic powder from rubbing off too readily after it has been applied. The aluminium and copper powders on the market are coated with stearin. This makes them difficult to wet with water, but special experiments have shown that the behavior of copper or aluminium with kerosene is qualitatively the same whether the stearin coating is removed with ether or not.

Similar results can be obtained with colloidal solutions. Isobutyl alcohol⁵ was added to a colloidal gold solution obtained by reducing gold chloride with carbon monoxide. When the two liquids are shaken, the gold forms a thin film at the interface. This film is violet blue to blue green by transmitted light and golden by reflected light. A thin water film forms between the isobutyl alcohol and the glass, and the gold concentrates in the dineric interface thus formed, making the alcohol appear uniformly gold-plated. With ether the gold film rises high above the level of the two liquids. With carbon bisulphide the adherent film of gold appears blue. When the carbon bisulphide is broken into drops by shaking, each drop appears blue. When a blue gold was obtained by reducing gold chloride with phosphorus dissolved in ether, the gold went into the dineric interface. When a brownish-red gold was obtained in this way, it remained in the water phase and showed no tendency to pass into the interface. This difference is undoubtedly due to an adsorption of some-

*A paper read at the joint meeting of the New York sections of the American Institute of Mining Engineers and the American Electrochemical Society on May 12, 1916.

¹Rayleigh, *Scientific Papers*, 3, 354 (1902).

²Fockels, *Wied. Ann.* 67, 669 (1899).

³Cf. Hofmann, *Zeit. Phys. Chem.* 83, 385 (1913).

⁴Bancroft, *Trans. Am. Electrochem. Soc.* 23, 294 (1913).

⁵Reinders, *Zeit. Kolloidchemie*, 13, 235 (1913).

thing at the surface of the gold, because Reinders found that 0.005 per cent gum arabic prevents colloidal gold from passing into the ether water interface. With carbon tetrachloride, carbon bisulphide, or benzene, the gold goes into the interface as before, but the gum arabic prevents its changing from red to blue.

Colloidal arsenic sulphide goes into the dimeric interface with amyl alcohol or isobutyl alcohol, but stays in the water phase when carbon tetrachloride, benzene or ether is the second liquid. India ink goes completely into the interface with amyl alcohol, carbon tetrachloride, or benzene; it goes partly into the interface with isobutyl alcohol, and stays entirely in the water phase when ether is the second liquid.

Winkelblech⁶ has shown that mere traces of gelatine in water can be detected by shaking with organic liquids, the gelatine concentrating at the interface to form a film. "A heavy precipitate was obtained when 10 c.c. of a solution containing 0.234 g. gelatine per liter was shaken with benzene. Precipitates were also obtained when the gelatine solution was diluted tenfold, twenty-fold and even forty-fold, provided 10 c.c. solution were taken for the test. At the highest dilution the concentration of the gelatine was 0.06 g. per liter, and there were consequently 0.06 mg. in the 10 c.c. taken for the test. This seemed to be about the limit at which a precipitation could be detected definitely. . . . Some other colloids behave like the glue colloid (glutin), and can be shaken out of their solutions. Other hydrocarbons are also effective, so that the phenomenon seems to be a general one. Precipitation was obtained with albumin, water-soluble starch and soap, as well as with resin dissolved in very dilute caustic soda. The colloids grouped as mucin can be precipitated from urine and the proteins from beer. It is worth noting that tannin can be precipitated but not gallic acid.

The hydrocarbons which can be used are: kerosene, liquid paraffin, benzene, chloroform, and carbon bisulphide [in addition to benzene]. The result varies from case to case. With the hydrocarbons which are lighter than water, the precipitate floats on the water; with the denser hydrocarbon the precipitate is below the water layer. The emulsions which form seem to have very nearly the same density as the organic liquid used. It is not possible to get the precipitation with all liquids which are non-miscible or slightly miscible with water. Experiments with ether were entirely unsuccessful.

As a complement to the action of hydrocarbons on aqueous colloidal solutions it was found that fats dissolved in hydrocarbons or similar liquids can be precipitated in the surface film by shaking with water. Precipitations were obtained with butter, olive oil, lanolin, and vaseline. It was also found that the emulsions of heavy hydrocarbons or carbon bisulphide with the fats of low specific gravity also accumulate below the water layer, only a small portion being carried to the surface by adhering air bubbles. When water is used for shaking out, the precipitation is very slight. With a slightly alkaline solution such as dilute lime water, heavy voluminous precipitates were obtained while a transparent layer of fat is obtained when a slightly acid solution is used. With concentrated alkali or acid solutions, viscous emulsions are obtained which hold fast considerable amounts of solution."

Winkelblech patented the use of such organic liquids as kerosene for clearing sewage by shaking out the colloidal oxidizable matter. The method was not a success commercially, because less than 40 per cent of the oxidizable matter was removed.⁷

Briggs⁸ has shown that sodium oleate is removed from

solutions of different strengths during the process of emulsifying benzene, and that the amount of this removal depends upon the strength of the soap solution and the specific surface of the benzene phase. Rayleigh⁹ has observed an interesting case in which dust goes into the water layer. "In the course of some experiments last year, in illustration of Sir George Stokes' theory of ternary mixtures, I had prepared an association¹⁰ of water, alcohol, and ether, in which the quantity of alcohol was so adjusted that the tendency to divide into two parts was almost lost. As it was, division took place after shaking into two nearly equal parts, and these parts were of almost identical composition. On placing the bottle containing the liquids in the concentrated light from an arc lamp, I was struck with the contrast between the appearance of the two parts. The lower, more aqueous, layer was charged with motes, while the upper, more ethereal, layer was almost perfectly free from them. Some years ago I had attempted the elimination of motes by repeated distillation of liquid in vacuum, conducted without actual ebullition, but I had never witnessed as the result of this process anything so clear as the ethereal mixture above described.

"The observation with the ternary association, which happened to be the first examined, is interesting, because the approximate equality of the liquids suggests that the explanation has nothing directly to do with gravitation. But the presence of the alcohol is not necessary. Ether and water alone shaken together exhibit the same phenomenon. It would appear that when the two liquids are mixed together in a finely divided condition, the motes attach themselves by preference to the more aqueous one and thus when separation into two distinct layers follows, the motes are all to be found below."¹¹

"I have lately endeavored to obtain some confirmation of the views above expressed by the use of other liquids. It would evidently be satisfactory to exhibit the selection of motes by the upper, instead of by the lower, layer. Experiments with bisulphide of carbon and water, and also associations of these two bodies with alcohol, which acts as a solvent to both, gave no definite result, perhaps in consequence of a tendency to the formation of a solid pellicle at the common surfaces. But with chloroform and water, and with associations of chloroform, water and acetic acid (acting as a common solvent) the experiment succeeded. The motes were always collected in the upper, more aqueous, layer, even when the composition of the two layers into which the liquid separated was so nearly the same that a few additional drops of acetic acid sufficed to prevent separation altogether."

The reverse case appears to occur with white lead. J. Cruickshank Smith¹² says: "During recent years the practice has been adopted, largely among white-lead corrodors who grind their own white lead in oil, of doing away with the final drying of the white lead pulp as it comes from the washing process, and grinding or beating up the pulp (exhausted of water until the proportion of the latter does not exceed about 20 per cent) with a suitable quantity of refined linseed oil. This process depends on the greater surface attraction which white lead particles offer to linseed oil than to water. It enables considerable economies to be effected in the manufacture of ground white lead, and it eliminates risk of lead poisoning during one of the most dangerous parts of the white lead manufacturing process." Not

⁶Scientific Papers, 3, 569 (1902).

⁷Association is here employed as a general term denoting the juxtaposition of two or more fluids. Whether the result is a mixture depends upon circumstances.

⁸The clearness of the upper layer, after a mixture of ether and alcohol has been shaken up with dust, had already been observed and explained, much as above, by Barus, Amer. Jour. Sci. (3) 37, 122 (1889).

⁹The Manufacture of Paint, 92 (1915).

¹⁰Zelt. angew. Chem. 19, 1953 (1906).

¹¹Blitz and Kröhnke, Zelt. angew. Chem. 20, 883 (1907).

¹²Jour. Phys. Chem. 19, 210 (1915).

enough oil is added to float the white lead and consequently the white lead carries the oil down with it,¹² leaving the water as upper phase.

That the adhesion between the solid and the liquid may be very marked is shown by the behavior of the so-called water wings. These consist of a closely woven fabric readily permeable to air when dry. When thoroughly wetted, the film of water is strong enough to permit of the wings being blown up enough to float a person with ease. Though I know of no direct experiments on the subject, it seems probable that the gas pressure in some sandstone anticlines may result from the oil being displaced by water, which would wet the porous rock more readily than does the oil.

In many of the cases where oil flotation has been employed we have a sulphide ore, which is much more readily wetted by oil than by water, in presence of a siliceous gangue, which is much more readily wetted by water than by oil. Consequently the gangue tends to stay in the water phase while the ore is carried up by the oil. The use of an acid solution is natural, because oil adsorbs hydroxyl ions,¹³ and these latter cut down the adsorption of the solid. Nagel¹⁴ found that when precipitated chromic oxide is shaken with water and benzene, it goes into the dimeric interface, but is precipitated from it by addition of caustic alkali. Zinc sulphide is also precipitated from the dimeric interface of kerosene and water by addition of alkali. I am aware that modern flotation practice is tending to the use of neutral or slightly alkaline solutions, but in such cases air plays an important part, and the use of mixed oils may introduce a new set of factors. It must also be remembered that acid in ore flotation does not act because of a replaceable hydrogen atom, but by cutting down the concentration and consequently the adsorption of hydroxyl ions. If calcium ions, for instance, cut down the adsorption of hydroxyl ions sufficiently, calcium hydroxide would behave like an acid, so far as ore flotation is concerned, though it would be alkaline to litmus paper. Somewhat similar cases are known. Under electrical stress albumin moves to the cathode in acid solutions, and also in calcium chloride solutions. The effect is not a question of acidity. The direction in which the albumin moves depends upon the charge of the ion adsorbed in excess. The hydrogen cation and the calcium cation are each adsorbed more than the chlorine anion, and consequently the albumin moves to the cathode in these two solutions. I do not know whether anything of this sort is a factor in modern flotation practice.

Since no systematic experiments have been made to determine the exact effect of temperature, we do not know to what extent the apparent advantages of a heated solution are due to a relative change in the selective adsorption, to a change in the relative densities of the two liquids, or to a change in the viscosities. It seems probable that all three changes are factors, but that the change in the selective adsorption is the important one. Of course the absolute adsorption must decrease with rising temperature, but the selective adsorption may, and probably does, increase with rising temperature. At still higher temperatures the decrease in absolute adsorption becomes too serious and there is therefore a maximum temperature which is not necessarily the same under varying conditions.

We now have to consider the part played by air in flotation. Since the density of air is low, it is clear that a film of adsorbed air or an attached bubble of air will be very effective in floating a solid particle. If we like,

we may consider air as an extreme case of a second liquid phase, in which case we may have the solid remaining in the air phase under suitable conditions, concentrating in the interface, or remaining in the water phase. If a piece of metal covered with an air film be laid very carefully on the surface of water, the water may wet it so slowly that the metal will float if it is not too heavy. If the surface of a copper wire be converted to sulphide, it will float more readily because the adsorption of air is more marked. If we have a stearin surface, as in the case of copper powder or aluminium powder, the water has still less tendency to wet the solid, and it becomes quite difficult to cause the commercial copper powder or aluminium powder to sink in water. This difference in readiness to wet is made use of in the film flotation processes of Wood and McQuisten.

The concentration of the solid at the interface occurs when a skin forms over the surface of boiled milk or of cocoa or of a peptone solution. I do not know of any case of ore flotation analogous to this, but doubtless one could be devised if anybody was interested in it. In the case of soap solutions we have a partial concentration in the surface, but the bulk of the soap remains distributed through the water phase. The soap, however, adsorbs so much air that boiling-point determinations on concentrated solutions are worthless.¹⁵

The selective adsorption of gases and vapors by solids is a matter of common knowledge.¹⁶ The film of condensed gas shows itself in the abnormal mobility of very fine powders, in the fact that two pieces of a broken object will not reunite when pressed together, in a resistance to the passage of an electric spark between solid terminals, and in the behavior of the crystal detector and the coherer as used in wireless telegraphy. All liquids show selective adsorption of gases and vapors. The most striking way in which this shows itself is in the form of the splashes when a drop of water, 5 mm. in diameter, falls on a sheet of water from a height of less than 1 meter. It is this film of adsorbed gas which tends to prevent the coalescence of two soap-bubbles or two impinging jets of water when there is no electrical stress.

Since water removes air more or less quickly from practically all minerals, selective flotation from already wetted ore is practically impossible, and one must have recourse to the combined effect of oil and air. It so happens that in acid or neutral solutions air seems to be adsorbed by organic liquids much more readily than by water.¹⁷ Into 100 c.c. approximately normal caustic potash solution 0.5 c.c. chloroform was dropped from a 5 c.c. pipette. The chloroform did not seem to spread out on the surface before sinking so much as it did with water. The globules sank to the bottom and flattened out; they were distinctly not very mobile, and seemed to sink to the bottom of the vessel. When the chloroform was dropped into the water it broke up into a number of drops which did not agglomerate so easily as in the water solution. In fact, quite a little shaking was necessary in order to make them coalesce. At first no air bubbles could be detected, but after standing for five minutes a very small bubble appeared on the chloroform. Sulphuric acid was then added until the solution became acid. The flattened drop of chloroform at once assumed the shape of a round ball and became mobile. An air bubble also appeared in the center of the drop.

"Into 100 c.c. approximately normal sulphuric acid solution 0.5 c.c. chloroform was dropped as before. The chloroform spread all over the surface and then sank

¹² My attention was first called to this by Mr. T. R. Briggs.
¹³ Twomey, *Jour. Phys. Chem.* 19, 360 (1915).

¹⁴ *Jour. Phys. Chem.* 19, 570 (1915).

¹⁵ McBain and Taylor, *Zeit. phys. Chem.* 76, 182 (1911).
¹⁶ Bancroft, *Jour. Phys. Chem.* 20, 1 (1916).

¹⁷ Twomey, *Jour. Phys. Chem.* 19, 360 (1915).

through the solution in small drops, forming round globules with air bubbles clinging to each. It was hard to get rid of the bubbles on the chloroform drops by shaking; as soon as one was driven off another bubble appeared exactly in the center of the drop. When the bubbles were dislodged from the drops, they rose to the surface carrying with them some chloroform, a part of which remained on the surface until it evaporated, while the rest sank back to the bottom of the solution. The globules were very mobile and coalesced readily. Caustic potash was added to the solution, making it alkaline. The chloroform globule flattened immediately and the air bubble in the center disappeared. In still another experiment an acid solution was made alkaline, then acid, and then alkaline again. The result confirmed Wilson's experiments,¹⁸ for the drop of chloroform was always flat in the alkaline solution and always round in the acid solution. There is scarcely any difference to be noted between the shape of the drop in acid solution and in pure water. The same results were obtained when NaOH and HCl were substituted for KOH and H₂SO₄.

"In one experiment in a nitric acid solution the temperature was raised to about 40 deg. C. Bubbles seemed to shoot from all parts of the solution to the chloroform drop. When they had formed a large bubble in the center of the chloroform, the air bubble rose to the surface of the solution as in the other cases."

Of course, it does not follow that the relative adsorption of gas is always greater for oil in acid solution, but merely that this seems to be true in the cases hitherto studied. It is purely an empirical observation. Another interesting fact is the difficulty that is experienced in getting air bubbles to attach themselves in some cases to the oil films surrounding the solid particles. Some people have even claimed that nascent gas is essential, but this is absurd. If the air bubble comes in contact with the oil it will adhere; but it is not easy to bring about this contact. It can be done by vigorous agitation or by causing dissolved gas to come out of solution, but the essential thing is merely to bring the gas in actual contact with the oil.

A large air bubble will have a relatively great lifting power, but it will also tear loose very readily from an oiled particle. We shall get better results if we produce a froth consisting of bubbles of air in oil. Under ideal conditions the film around the bubbles will consist of particles coated with oil. We cannot get a froth with a pure liquid and air. There must be present a third substance in colloidal solution which will tend to form an emulsion of air in the liquid in question, for a froth is essentially a very concentrated emulsion of air in liquid. If the colloidal material is not present in the liquid it must be added. It has often been overlooked that what is needed for ore flotation is a froth of air in oil. People have said to themselves that froth is what is needed and have added saponine and other things with disastrous results. Saponine produces a froth, but it is a froth of air in water and therefore plays havoc with flotation. The things which have proved successful are substances like sodium resinate so called, which produces a froth of air in water in an alkaline solution but one of air in oil in an acid solution, because free rosin forms a colloidal solution in oil but not in water. Mr. Van Arsdale has worded the matter in what seems a different way by saying that the substance added must tend to emulsify water in oil and not oil in water. This is very nearly the same thing, because substances which form colloidal solutions in oil and not in water tend to emulsify water in oil." I

have preferred to consider the oil-air interface and Mr. Van Arsdale the oil-water interface, but the two points of view lead to the same conclusions in almost all cases.

So far, we have been considering the case where we have a fair amount of oil. If we cut the amount of oil down almost to a vanishing quantity another factor comes in, namely, air flotation. When sufficient quantities of oil are used, the air floats the oil and the oil floats the ore. The ore is inclosed in a drop of oil having the properties of matter in mass and sinks to the bottom of the drop of oil, distorting it to a greater or lesser extent. If the amount of oil is decreased sufficiently, we no longer have an oil drop surrounding the particle of ore, but an oiled particle, the lower part of which is, or may be, in contact with water, while the upper part is in contact with air. We are therefore getting air effect in addition to the oil effect. I do not know the relative importance of these two effects, but it has been claimed—and disputed—that the modified air flotation is of much greater value than the other. In the Wood and the McQuisten processes there is no doubt but that the separation would be more effective if it were possible to cover the ore particles with a thin film of stearin, leaving the gangue particles uncoated. It is very difficult to wet the stearin-coated commercial copper and aluminium powders, and it is therefore very difficult to make them sink under water. In the modern processes of ore flotation using very little oil per ton, we get a thin coating on the ore analogous to the stearin coating on the copper or the aluminium powder. It is possible that the air film may surround the oiled particle completely so that the oil does not come in actual contact with the water. In that case we are back to a straight air flotation of oiled particles. This point calls for further study because, if established, it would have a very important bearing on the future development of the subject.

It is under these circumstances that addition of more oil causes the ore to cement together and sink. The reason for this will perhaps be seen more easily if we consider the analogy of sand and water. When enough water is mixed with sand, we get a quicksand over which it is unsafe to walk. With only a little water we get a plastic mass over which it is a pleasure to walk and out of which children can make forts, pies, etc. When the sand dries out more, air gets in between the grains, and the walking becomes hard, though the sand is by no means dry from a chemical point of view. When the amount of oil round the ore particles is sufficiently small, the air gets in and makes a froth possible. With more oil we get a plastic mass; with still more we get the bulk oil process.

Anderson¹⁹ classifies flotation oils as "frothing" and "collecting" oils.²⁰ "There is at times some difficulty in grasping the distinction between frothers and collectors as such, for one oil in itself may, and often does, possess both frothing and collecting properties. The action of a frothing oil is such as to produce froth in greater or less amount, dependent on the frothing power of the oil. A collecting oil has a collecting power for sulphides in preponderance over its frothing action, being therefore, so to speak, a poor frother; a collecting oil may have simply a collecting action and little or no frothing action. As stated in the foregoing, some oils combine both the properties of frothing and collecting in variable degrees of each.

"The most successful frothing oils include the pine oils, cresylic acid and turpentine and other pyroligneous products from the distillation of wood—notably methyl alcohol." The coal tar phenols and their near

¹⁸Wilson, Jour. Chem. Soc. 1, 174 (1848).
¹⁹Bancroft, Jour. Phys. Chem. 17, 515 (1913).

²⁰Met. & Chem. Eng. 14, 136 (1916).

²¹Van Arsdale calls them "foamers" and "ollers."

²²This must be an error. W. D. B.

derivatives, and almost all of the so-called essential oils are good frothers. The essential oil of eucalyptus finds favor, particularly in Australian practice, on account of relatively low cost and immediate supply. Castor oil, to which reference has already been made, when mixed 1:4 with kerosene has found application. The more volatile products of petroleum, including kerosene and gasoline [?] have been successful frothing oils."

"So-called mineral oils and tar oils do not generally form a good flotation froth, but have a marked selective action on the sulphide minerals. Among the mineral oils are included the following: asphaltum base, crude petroleum, refined oil, gasoline, burning oil, creosol, and coal-tar creosotes."

"It is found that thick oils tend to form viscous, coherent flotation concentrates, while thin oils form less coherent masses. The action of coal tar in stiffening a weak, ephemeral froth is indicative of the former. In general the essential oils give a coherent froth and satisfactory extraction; oils like oleic acid or candle-maker's red oil, petroleum, and lubricating and engine oils have a strong tendency to produce heavy, thick granules which will not float. Oleic acid has a well-marked power to float silicates."

If a pure liquid does not form a froth with air, it follows that no oils can be frothing oils except in so far as they contain suitable colloidal material suspended in them. In some cases this colloidal material is rosin; in other cases it is for the organic chemist to decide just what the special substance is. Since the good effect of the frothing oils is due to the colloidal substances, it is a question of cost whether it is more advantageous to mix a frothing oil with a collecting oil or to add the constituent which makes the former a frothing oil.

Since we are dealing with selective adsorption, we should expect to find that some oils would be better than others for certain purposes.

Anderson²⁴ states that "oils derived from the destructive distillation of wood, such as wood creosotes, pyroligneous acid, and the like, are found to give the best recovery on galena and zinciferous material; coal-tar products are better adapted to the successful flotation of copper-bearing minerals." There are no independent data from which this result could have been predicted.

Since flotation is due to selective adsorption, anything which will change the latter will change the degree and nature of flotation as far as the oil-water flotation is concerned. Adding a third liquid which is miscible with the other two, will tend to make the oil and water layers more nearly alike in composition and therefore in properties. This gives us a possibility of varying the selective adsorption within certain limits and its possibilities should be determined, even though there may be no economic advantages. Now that we are a little more clear as to the cause of frothing, it becomes possible to study new frothing agents more successfully and it is possible that some of these might have distinct collecting powers of their own. In some experiments recently made at Cornell by Mr. Briggs, it has been found that addition of salt made it easier to shake out colloidal ferric oxide with benzene. The reason for this seems to be that the salt makes the colloidal solution less stable. Any substance which prevents peptization in the water phase or promotes it in the oil phase will tend to increase the flotation. I do not yet know to what extent this is applicable to ore flotation; but Anderson²⁵ reports that experiments performed on a 60-mesh product from the Joplin district containing pyrite and galena in a calcareous gangue showed: that potas-

sium bichromate will deaden galena and permit the flotation of the pyrite; that sodium, potassium, and ferric sulphates promoted the production of clean concentrates; and that ferrous sulphate and cupric sulphate were very harmful to the successful flotation of this particular product, flotation being practically impossible in their presence. Anderson, of course, ventures no opinion as to why these salts act in this way; but it ought not to be difficult to work out a hypothesis if some data were forthcoming. The inadequacy of the present data is made clear by the statement of R. H. Richards that in the case of a certain Tennessee zinc ore the addition of a small amount of copper sulphate was necessary in order to bring about successful flotation. We have not yet made any experiments on the factors affecting the air flotation when the oil is reduced to a minimum, so I will not discuss that point at all.

There seems to be no reason to suppose that ore flotation has yet gone beyond the first stages of its development, and certainly a clear knowledge of the general theory should be a help in promoting the development.

Cornell University.

Newark Industrial Exposition

The Industrial Exposition being held at Newark, May 13 to June 3, in the First Regiment Armory, Jay Street (reached by Central Avenue trolley), is representative of the large manufacturing interests of that city. The exhibits are nicely arranged and include a large variety of industries. Among the industrial concerns having space are the following:

Gamon Water Meter Co., water meters.

Standard Oil Co. of New Jersey, Polarine oils and lubricants.

Newark Wire Cloth Co., wire cloth for industrial purposes and screens up to 300 mesh.

Crocker-Wheeler Co., generators, motors.

Westinghouse Electric Co., generators, motors, meters, Westinghouse Mazda lamps.

Murphy Varnish Co., varnish pigments, oils, small grinding rolls, filter presses, etc.

Celluloid Co., celluloid articles.

Driver-Harris Wire Co., Nichrome heat-resisting metal, Monel metal wire, small-wire drawing machine, demonstrating the drawing of copper wire from 0.016 in. to 0.0063 in.

Newark Leather Machinery Company, and combined exhibits of Newark's leather companies showing different leathers manufactured.

National Oil & Supply Co., Viscos oils and greases. Combination Rubber Mfg. Co., hose, packing, etc.

Thomas A. Edison, chemicals, phenol, aniline, etc.

Edison Storage Battery Co., Alkaline storage battery.

General Electric Co., Edison Lamp Works, Mazda lamps, historical exhibit showing development of incandescent lamp.

Anti-Hydro Waterproofing Co., waterproof liquid, waterproof paint, for brick, concrete, etc.

F. W. Horstmann Co., McDowell feed-water heater and purifier.

Bureau of Standards Analyzed Samples.—The Bureau of Standards, Washington, D. C., now has ready for distribution a new sample of its iron D, No. 6-b, replacing No. 6-a, which has been long out of stock. The composition of the new sample is: carbon, 2.39; graphite, 1.79; silicon, 2.59; titanium, 0.077; phosphorus, 0.531; sulphur (grav.), 0.046; manganese, 1.54; copper, 0.044; chromium, 0.014; vanadium, 0.025; nickel, 0.026. Until printed certificates can be had a provisional certificate of analysis, without details, will be furnished with each sample issued.

²⁴Met. and Chem. Eng. 14, 136 (1916).

²⁵Met. and Chem. Eng. 14, 137 (1916).

The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags

BY BOYD DUDLEY, JR.

In the fire assay of gold and silver ores by the crucible method it is the intention to effect complete decomposition of the ore by heating it, in the finely powdered state, in contact with suitable fluxes, and simultaneously to produce throughout the resulting slag a collector of gold and silver, consisting of small globules of metallic lead. When the fusion is complete, the lead collects as a liquid mass in the bottom of the crucible with the liquid slag above it. The lead is separated from the slag by pouring the fusion into a cone-shaped mold and there allowing it to freeze, whereupon the slag may be broken from the lead. The gold and silver collected by the lead during the fusion are recovered from it by cupellation.

Errors in the Crucible Assay

While complete collection by the lead of all gold and silver that may be present in the ore is the desired end in the crucible fusion, this result is generally not achieved. Various causes are responsible for the failure of the lead to completely fulfil its function. These are usually referred to as sources of error in the determination, or as just "losses," and they may be classified as follows:

1. Mechanical loss of material from the crucible may be caused by "dusting," by which term is meant the expulsion of dust from the crucible by gases that escape from the charge before fusion begins, or before fusion is sufficiently far advanced that the particles of ore are attached to, and weighted by, portions of slag. Mechanical loss from the crucible may also be caused by spitting or boiling-over during the fusion.

2. Due to an improper selection of fluxes, coarseness of the ore grains, insufficient time, or to other causes, a part of the ore may remain in the undecomposed condition at the time the assay is removed from the furnace. If the undecomposed particles happen to inclose gold or silver, or both, the amounts so inclosed will, of course, remain suspended in the slag.

3. There may be imperfect aggregation of the lead at the end of the fusion, or when the assay is poured shots of lead may become detached from the main body. With either of these conditions globules of lead may remain in the crucible or suspended in the slag, and in such cases, even if the decomposition of the ore is perfect and if the collection of the gold and silver by the lead is as complete as is possible, the assay is obviously defective. The error thus introduced is generally proportional to the amount of lead detached.

4. At assay temperatures gold and silver are both slightly volatile, and a small loss from the crucible may result from this cause.

5. Finally, it is necessary to consider the fact that with all other conditions perfect the lead will be unable to collect all of the gold and silver from the slag, because the slag possesses the power to dissolve these metals or compounds of them just as the lead dissolves the metals themselves. In other words, at the conclusion of the fusion the gold and silver will be distributed between the lead and the slag in a fairly definite manner, though the lead will have nearly all of the precious metals and the slag only a little.

The first three causes of error may, as a rule, be entirely prevented by the proper selection of fluxes and conditions. Although there is always a chance in pouring an assay that globules of lead may become

detached from the main body and may not again reach it before the slag solidifies. It may be well to note that errors due to this cause are quite frequent with slags containing excessive amounts of soda, which seem to prevent the lead from collecting as a single mass. Also, when the inner surface of the crucible becomes badly pitted and corroded during the fusion, shots of lead that cannot be poured from the crucible are more frequently observed than when the crucible is corroded to a less extent or in a more uniform manner.

The volatilization loss of gold and silver during the crucible fusion is probably negligible, because by the time the temperature of the charge has increased to the point where pure gold and silver might be appreciably volatilized, these metals are then present in the form of a very dilute solution in lead. In this condition their vapor tensions will be greatly reduced, and their tendency to volatilize correspondingly decreased.

It is with the fifth cause of error that the present paper deals, and then only with the case of silver. The retention of gold by slags was not studied.

The above rather exact classification of metal losses in the crucible fusion has been given in order to make clear the significance of the results obtained in the experiments described below. It is particularly desired to emphasize the distinction between the losses due to the second and third causes and that due to the fifth. As a general rule the errors due to all of these causes are collectively referred to as "slag losses," but it should be evident that the two first-mentioned are produced by purely physical conditions, while the last is essentially the result of a chemical phenomenon.

Equilibrium in the Crucible Fusion

In considering the case of the retention of gold and silver by assay slags its similarity to well-known cases of distribution equilibrium is apparent. In general, when two immiscible phases are in contact and a third substance soluble in both is added to them, a part of it will pass into solution in one phase and a part in the other. If opportunity is offered for the establishment of equilibrium, the solute will distribute itself between the two solvents in a perfectly definite manner, which is dependent only on the nature of the substances involved and on the temperature.

A simple case, wherein the solute occurs almost wholly in the same molecular state in the two solvents, is the distribution of succinic acid between ether and water.¹ When a small quantity of succinic acid is shaken with a mixture of ether and water, a state of equilibrium is attained, the conditions of which may be studied by allowing the two immiscible liquids to separate and determining the concentration of succinic acid in each. The results of such experiments conducted at constant temperature are given in Table I, wherein C_1 and C_2 denote the number of grams of acid dissolved in 10 c.c. of water and ether respectively.

TABLE I.—EQUILIBRIUM CONCENTRATIONS OF SUCCINIC ACID IN MIXTURES OF ETHER AND WATER AT CONSTANT TEMPERATURE

C_1	C_2	C_1/C_2
0.024	0.0046	5.2
0.070	0.013	5.2
0.121	0.022	5.4

It may be seen that here the ratio of the concentrations of the solute in the two immiscible phases is a constant at constant temperature, and is independent of the relative amounts of the two phases and of the

¹Nernst, Theoretical Chemistry, trans. 6th Ger. Ed., p. 496.

amount of the solute involved, so long as the solutions are sufficiently dilute. This condition is characteristic of those cases of distribution equilibrium where the solute occurs in the same molecular state in both phases, i.e., where a single molecular species is distributed between two immiscible liquids.

When the solute does not exist in the same molecular state or possess the same molecular weight in both phases, a state of equilibrium may be established in the same manner as in the above example, but there may not be the constant relation between the equilibrium concentrations that obtains in the simpler case. However, the fact remains that, whether the solute exists as a single molecular species in both phases, or whether chemical reactions occur within the phases and the solute exists in different molecular states in them, a state of equilibrium is generally attainable, the characteristics of which are dependent only upon the nature of the reacting substances and upon the temperature.

On first thought it may be difficult to perceive that these facts have any particular application to assaying. But they have—and not only to assaying, but to all metallurgical processes in which immiscible liquids are produced, such as metal and slag, matte and slag, matte and metal, etc. Without doubt, such equilibria are not only possible but the attainment of equilibrium conditions is even probable in the removal of impurities from white metal when the "selecting" process is in use, in the removal of impurities from iron and steel by washing the metal with slag, and in other processes of like nature. Furthermore, the question of metal losses in slags during smelting operations can be studied in a rational manner only when due consideration is given to the possible distribution equilibria that may be involved. Examples of such cases are the slag loss of copper in matte smelting, and the slag losses of lead and silver in lead smelting.

Returning to the specific case of the crucible assay, in the properly conducted fusion metallic lead is reduced in the form of innumerable liquid globules, which are disseminated throughout the entire charge at the time that the slag-forming constituents start to unite. These particles of lead remain suspended in the slag and are thoroughly agitated in contact with it during the boiling stage of the fusion, the boiling being produced by the expulsion of such gases as carbon dioxide, sulphur dioxide, etc., as are formed by the union of the various constituents of the charge. In the course of this agitation of lead and slag, while the two are in intimate contact, the free particles of gold and silver naturally become alloyed with the lead, while those particles of gold and silver that have not been liberated must await collection by the lead until their encasing or attached particles of gangue are dissolved in the slag. With this fact in view the importance of having lead suspended in the slag until the decomposition and dissolution of all ore particles is complete is quite evident.

Assuming complete decomposition of the ore to have been attained, some of the gold and silver may at first enter the slag in the dissolved condition, but, due to the thorough stirring of the charge by boiling and due to the large area of contact between the lead and the slag that results from the minute state of subdivision of the lead, almost perfect conditions obtain for the lead to remove from the slag such of this dissolved gold and silver as it can. On the other hand, if all of the gold and silver particles have been crushed free from the gangue and in consequence are collected by the lead in the early stage of the fusion, the agitation of the lead and slag will enable the slag to

remove such gold and silver as it can from the lead. In other words, the conditions are almost ideal for establishing that state of distribution equilibrium of gold and silver between lead and slag as corresponds to the nature of these substances and to the temperature of the fusion at the time.

If the process could be arrested just at the conclusion of the slag formation and as the lead is settling to the bottom of the crucible, and if the lead and slag could be completely separated from each other and analyzed, the results would doubtless indicate the truth of the above statements. However, the practical difficulties in the way of completing such an experiment are many, so for the present there is no direct evidence on this point.

Following the course of the crucible fusion still further, as the formation of the slag approaches completion and as its viscosity decreases due to increasing temperature, the smaller globules of lead coalesce to form larger ones, and the lead gradually settles through the still boiling slag to the bottom of the crucible. Here it should collect as a single liquid mass with the slag above. As a rule the slag continues to boil for a considerable time after the lead has reached the bottom of the crucible. The expulsion of gas from the charge is not yet complete, and the boiling produced by its continued evolution serves to still further agitate the slag in contact with the lead, though at a greatly reduced rate as compared with the agitation which occurs while the lead is suspended in the slag.

The agitation produced by the boiling of the slag after the lead has settled is accelerated by the presence of convection currents, which are caused by unequal temperatures within the crucible. Such currents are almost invariably present, and their action, as well as the effect of boiling, can be readily observed by watching the course of a crucible fusion in a pot furnace or in any furnace in which the surface of the slag is visible. Convection currents are produced in all cases where differences of temperature exist in different parts of the crucible, and such differences continue to exist until the very instant when the crucible and its entire contents arrive at the temperature of the surroundings. Moreover, the surrounding temperature must be uniform in the vicinity of the crucible in order to produce a perfectly quiescent fusion. Since these conditions are seldom or never encountered in the assay furnace, it is clear that, after all boiling due to the evolution of gas from the slag has ceased, the convection currents continue to remove the slag in contact with the surface of the lead and to replace it with fresh slag. The action of convection currents in thus stirring the slag after all boiling has ceased is a matter of common observation among assayers who have taken the trouble to watch for it.

It thus becomes evident that the possibility of establishing a distribution equilibrium of gold and silver between lead and slag does not cease to exist when the lead settles to the bottom of the crucible. Nor does the equilibrium that may be established while the lead is suspended in the slag necessarily persist after the metal has settled. On the other hand, if the temperature continues to rise, the continued boiling of the slag, coupled with the action of convection currents, will offer some opportunity at least for that readjustment of the equilibrium, which would tend to occur in response to the increase in temperature. Likewise, it is evident that such particles of gold and silver as may not be set free from attached particles of gangue up to the time when the lead settles from

the slag, are not hopelessly lost. If the temperature at the end of the fusion is sufficiently high, and if enough time is allowed to insure the complete dissolution of such encasing gangue particles, the gold and silver which they hold will have opportunity to reach the lead.

The above outlined course of a crucible fusion represents the ideal process. How closely the ordinary assay approaches this ideal is a question that can only be answered by a large amount of carefully conducted experimental work, which up to the present has not been attempted. But in this paper a few facts in regard to the final ideal conditions are presented.

Determination of Equilibrium Conditions

The experiments described below were undertaken with the intention of studying the effect of temperature and of slag composition upon the distribution of silver between metallic lead and certain commonly used types of assay slags. While the work is incomplete, it is thought that the results secured are of considerable value in indicating the effects of the factors mentioned, and also they perhaps offer some evidence in regard to the nature of such slag losses in general.

The method employed is simple in outline, but the manipulative details are somewhat tedious and troublesome. In each experiment two crucible charges containing the slag-forming constituents in the desired amounts are prepared. They are identical in composition with the exception of the silver content. To one a quantity of silver is added, which imparts to the fused slag a higher silver concentration than corresponds to the ultimate equilibrium concentration. To the other less silver is added than corresponds to this concentration. In all cases the silver is added in the form of an argentiferous litharge of known silver content, which is prepared by adding a solution of silver nitrate to finely powdered yellow litharge, drying the mixture, passing it through a 100-mesh sieve, and determining the silver in the product by corrected assays. At first it is necessary to guess at the amounts of silver to be employed, but as the work proceeds very close estimates of the amounts required can be made.

The crucibles and charges are introduced into an electric resistance furnace, and the charges are fused. The furnace is then brought to the desired temperature, which can be maintained within ± 3 deg. C. for considerable periods of time by regulating an external resistance in series with the furnace winding. When the desired temperature has been attained, a button of lead containing a known amount of silver is dropped into each crucible, the quantities of lead and of silver being the same in both cases. Then, by means of clay stirrers, which have been previously brought to the temperature of the furnace, the slags are thoroughly and rapidly stirred. In this manner an opportunity is offered for the establishment of equilibrium conditions in the distribution of silver between the lead and the slag. That such an equilibrium is attained is shown by the fact that in the one crucible containing the silver-rich slag the silver passes from the slag to the lead, while in the other crucible the reverse of this action occurs. In the end both slags attain the same concentration with respect to silver.

After stirring, which is continued for from 15 to 60 min., depending on the viscosity of the slag, its tendency to corrode the crucible, and whether the stirring is done manually or mechanically, the crucibles are removed from the furnace. The slag and lead

are not poured as in the ordinary assay, because of the danger of detaching globules of lead from the main body. If this occurs and if one or more small globules remain in the slag and are not discovered before the slag is assayed, the results are worthless. This is true because the concentration of silver in the slag is so small in comparison with its concentration in the lead that the inclusion of even a minute globule of the silver-rich lead introduces a very large error. On this account only about four-fifths of the slag is poured from the crucible, the remainder being allowed to remain with the lead. The poured portion serves as a sample of the slag. It is crushed and screened through an 80-mesh sieve, and a weighed portion, 100 to 150 g., is assayed for silver.

In assaying the slag 3 to 4 g. of argol is added, and the resulting charge is fused and poured. The lead button, weighing from 25 to 30 g., is cupelled in the usual manner. All of the slags that have been studied contain enough litharge to permit the application of this method. In some cases a little soda is added to replace the litharge reduced; in others borax glass is added to reduce the corrosive effect of the slag upon the crucibles. That this method makes a sufficiently complete recovery of the silver for practical purposes is shown by the fact that numerous assays of the second slag have recovered amounts of silver ranging from nothing to only half of 1 per cent of that recovered in the first assay.

The slag and lead left in the original crucible are allowed to freeze, after which the button of lead is recovered by breaking the crucible. It is weighed, and, from the final weight and the amount of silver originally added to the lead, the concentration of silver in the metal is calculated. Usually the amount of silver that passes from the slag to the lead or from the lead to the slag is so small a proportion of the total present in the lead that it may be neglected.

The furnace in which the slags were formed and held at constant temperature was constructed by winding an ordinary clay muffle (Battersea KK) with Chromel resistance wire, the strands being 0.5 in. apart. After the wire was in place the outside of the muffle was plastered with a mixture of fine dead-burned magnesite and sodium silicate solution. The muffle was then placed with the open end up in a Rockwell Engineering Company stationary, oil-fired furnace, which could be temporarily spared for the purpose, and the space between the muffle and the lining of the furnace was packed with a mixture of light-calcined magnesia and asbestos. Reference to Fig. 1 will make clear the details of furnace construction. In this figure are also shown the positions of the crucibles, stirrers, and pyrometer.

With the crucibles in place and after a state of thermal equilibrium had been established, the variation of the muffle temperature from the bottom of the crucibles to the level of the slag line was less than 5 deg. C. In controlling the temperature during an experiment the thermo junction was placed between the crucibles and 1.5 in. above the crucible support, this point being about the average elevation of the charges during the stirring. All temperature measurements were made with a platinum-rhodium thermocouple, which was protected by a fused silica tube. The indicating instrument was a W. Paul millivoltmeter, and the cold junction of the couple was maintained at 0 deg. C.

The stirrers were made of Woodland fire-clay crushed through a 40-mesh sieve, mixed with an equal volume of crushed crucible scraps of the same size. The mixture was made plastic by the addition of

water, and molded into cylinders, $4\frac{1}{2}$ in. long by $1\frac{1}{2}$ in. in diameter, with a round hole in one end $\frac{1}{2}$ in. in diameter by $1\frac{1}{2}$ in. deep. After slow drying, the cylinders were burned at about 1250 deg. C., and then mounted on a No. 10 B. & S. gage Chromel wire. A spiral on the end of the wire was inserted into the hole in the clay piece and cemented in place with a mixture of magnesite and sodium silicate solution.

During an experiment a clay piece dips into the slag in each crucible, and the ends of the wires project through the lid of the furnace. By raising and lowering the stirrers the slags are very effectively agitated in much the same manner as is the cream in an old-fashioned, vertical-dasher churn.

A small motor was harnessed to a "walking beam" as is shown in Fig. 1, and at low temperatures, when the

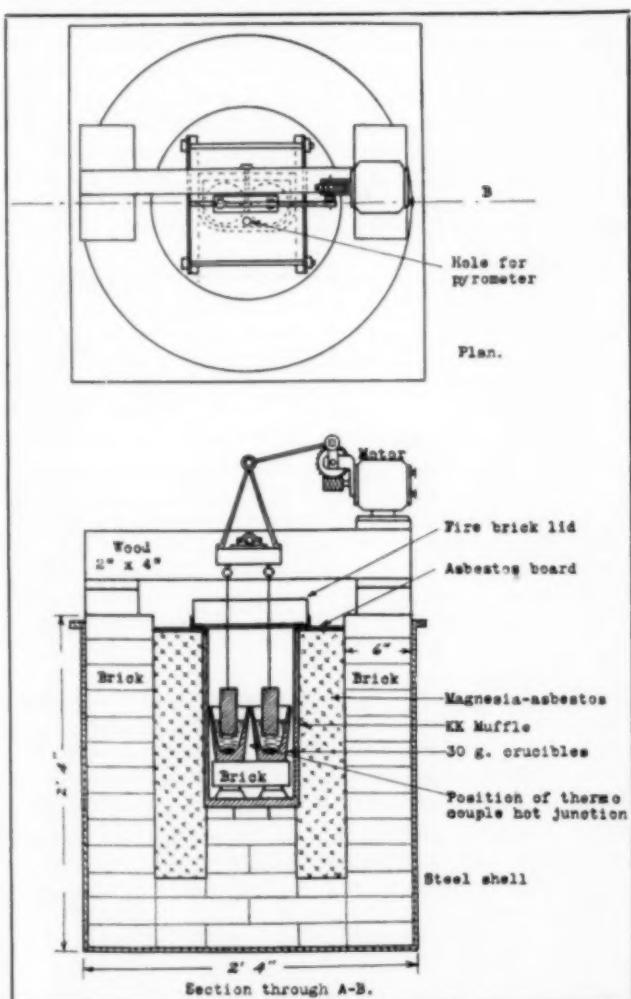


FIG. 1—ELECTRIC FURNACE

slags were viscous and not too corrosive to the crucible, the stirrers were suspended from the ends of the beam. The beam made about 60 oscillations per minute, and by the use of this device much of the tedium of hand stirring was avoided.

Compositions of Slags Investigated

The compositions of the slags that were worked with, exclusive of the amounts of silver, are shown in Table II. Table III shows the quantities of various reagents required to produce 100 g. of these slags.

It will be seen that these slags range in composition from 25 per cent litharge to 90 per cent litharge, and in oxygen ratio from 1.71 to 0.48. Only the commonly used reagents were employed, and slags containing oxides of metals other than lead were not studied. While these compositions will, of course,

TABLE II.—COMPOSITIONS OF SLAGS

Slag No.	Na ₂ O, Per Cent	PbO, Per Cent	SiO ₂ , Per Cent	B ₂ O ₃ , Per Cent	O in Acid, O in Base
1	4.24	89.7	3.58	2.48	0.48
2	3.15	85.0	7.00	4.85	1.02
3	12.65	71.65	10.74	4.96	1.08
4	24.79	48.30	24.12	2.79	1.50
5	38.78	24.90	31.14	5.18	1.71

TABLE III.—REAGENTS FOR 100 G. OF EACH SLAG

Slag No.	Na ₂ CO ₃ g.	PbO g.	SiO ₂ g.	Na ₂ B ₂ O ₃ g.
1	5.36	89.70	3.58	3.58
2	1.71	85.00	7.00	7.00
3	17.90	71.65	10.74	7.10
4	40.25	48.30	24.12	4.03
5	60.60	24.90	31.14	7.48

not find favor with everyone as being suitable for practical assaying, they do serve the purpose of indicating the effects of the principal factors that govern the solution loss of silver in the slag. Consideration of the experimental results will show that these factors are the percentage of litharge and the temperature.

None of the materials employed in the crucible charges was subjected to any special preparation, excepting the soda. This was calcined at a temperature near its melting point in order to remove water and to dissociate any bicarbonate that might be present.

While the reagents were mixed in the proportions specified in Table III, the actual compositions of the slags were not the same as the calculated compositions. Corrosion of the crucible and stirrer serves to dilute the slag, and a slight volatilization of litharge always occurs. The latter factor, however, was found to be of less importance than the first. The variations of the slags secured from the calculated compositions were not determined by analyses, nor were attempts made to estimate them closely. For the original purpose of this work it seemed sufficient to specify the reagents used and the slags that they would yield if undiluted. While it is recognized that the actual slags will contain somewhat more of silica and alumina and less of litharge than the calculated compositions, nevertheless the uncertainty introduced by neglecting this factor is in most cases within the limits of other experimental errors, which arise from conditions that are independent of this one.

The Distribution of Silver

In the first series of experiments slag No. 3 was employed. Charges were made to yield 175 g. of this slag. They were melted in pairs with the amounts of argentiferous litharge required to give the desired initial silver concentrations to the slags. Each pair of charges was brought to 837 deg. C., and a button of silver lead alloy weighing 25.0 g. was added to each crucible, after which the slags were stirred, poured and assayed, as has been described in a preceding paragraph.

The results obtained from eight fusions of slag No. 3 at 837 deg. C. are shown in Table IV.

TABLE IV.—DISTRIBUTION OF SILVER BETWEEN SLAG NO. 3 AND LEAD AT 837 DEG. C.

a	b	c	d	e	f	g
0.0040	0.0051	24.95	506.3	20.3	3980	3830
0.0060	0.0049	25.00	505.8	20.2	4120	3960
0.0075	0.0101	24.90	1025	41.2	4080	3920
0.0120	0.0099	25.00	1024	41.0	4140	3980
0.0120	0.0143	25.00	1548	61.9	4330	4160
0.0180	0.0145	25.00	1548	61.9	4270	4110
0.0150	0.0198	24.90	2031	81.5	4120	3960
0.0250	0.0198	24.90	2034	81.6	4120	3960

Average corrected ratio of concentrations = 3980

Explanation of table:

a = mg. of silver per g. of slag before lead is added.
b = mg. of silver per g. of slag after stirring with lead.

c = g. of lead-silver alloy at end of experiment. The amount added to each crucible was 25.0 g.

d = mg. of silver present in the alloy at the start.

e = mg. of silver per g. of alloy at the end = d/c.

f = mg. of silver per g. of alloy / mg. of silver per g. of slag.

both at the end of the experiment = e/b.

g = corrected ratio of equilibrium concentrations as explained below.

The concentration of the silver in the lead or metal phase at the end of the experiment was obtained by dividing the weight of silver originally employed by the weight of alloy remaining. On the other hand, the concentration of silver in the slag could not be so calculated, but had to be determined by assaying. Therefore not all of the silver present in the slag was recovered, the principal loss being that due to cupellation.

In the first experiments attempts were made to determine the cupellation losses and to apply appropriate corrections, by employing checks made up of proof silver and lead in amounts approximating those present in the assay buttons. But it was found that owing to the small amounts of silver present the agreement between checks was hardly close enough to warrant their use. The losses from carefully prepared checks cupelled under apparently identical conditions would vary from about 3 per cent to 6 per cent of the silver originally taken. From the results of thirty such checks it was found that, under the conditions of cupellation employed, an addition of 4 per cent to the weight of silver remaining after cupellation would provide as reliable a means of correcting for cupel losses as could be conveniently employed. This is, of course, the average correction, and its application to an individual result cannot be expected to invariably yield the true silver content of the lead button before cupellation. But the application of this correction to several results will yield an average corrected result that will approximate the truth. Therefore, the ratios of the concentrations of silver in the lead and silver in the slag, shown in column "f" of Table IV, have been divided by the factor 1.04 and entered in column "g" as corrected ratios. This produces the same result as if the slag assay values had been multiplied by this factor.

The results shown in Table IV prove conclusively that at constant temperature a definite distribution of silver between lead and slag will occur, the silver passing either from the slag to the lead or from the lead to the slag as may be necessary to establish the equilibrium. It is also shown that as the silver concentration in the lead increases its concentration in the slag, required to produce equilibrium, will increase in direct ratio. That is, the ratio of the equilibrium concentrations of silver in metallic lead and in a slag of given composition is a constant, at constant temperature. Thus it appears that this distribution possesses the characteristics of one in which the solute has the same molecular weight in both solvents. In this respect it resembles the succinic acid, ether, and water system mentioned above.

The limits of concentration of silver in the lead, shown in Table IV, were chosen because with lower concentrations the difficulty of obtaining exact assays of the slag is greatly increased; while with higher concentrations, it was anticipated that too great a variation of the composition might produce corresponding changes in the nature of the metal phase, and thus alter the characteristics of the equilibrium. In subsequent work a mean between these extremes was selected, and silver-lead alloys containing approximately 1 g. of silver in 25 g. of the alloy were used.

Slag No. 3 possesses very favorable properties, which allow experiments to be made over a greater range of temperature than is possible with any of the other slags. Its formation temperature and melting point are low, and at the low temperatures it is quite fluid without being excessively corrosive to the crucibles at the higher temperatures. The results of

further experiments to determine the distribution ratio of silver between this slag and lead are given in Table V. The details of the observed data and the methods of calculation having been shown in Table IV, only the figures essential to a clear presentation of the facts are given in the following tables.

Owing to the fact that the furnace in which the melts were made was wound with a nickel-chromium resistance alloy, it could not be used at temperatures above 1050 deg. C. without frequent renewals of the resistor. Consequently, the distribution ratios of Table V that correspond to the temperatures 1143 deg. and 1173 deg. C. were determined by a method which differs somewhat from the one already described.

For determinations at these temperatures a coke-fired muffle furnace was employed. Two crucibles and their charges were placed in the back of the muffle. In front of these were placed empty crucibles of the same size, which served to restrict the air circulation and to produce a very uniform temperature around the charged crucibles. Temperature measurements were made by sighting a Morse thermo gage through a small hole in the muffle door upon a crucible painted with ferric oxide, which stood in an inverted position

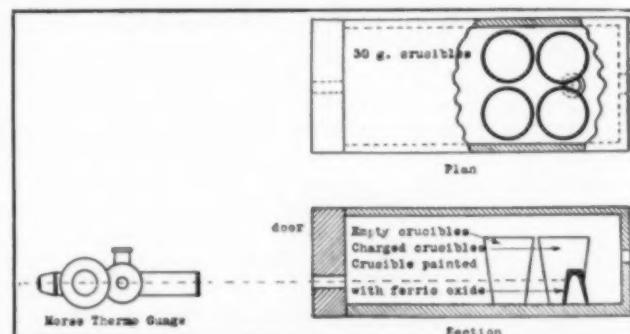


FIG. 2—ARRANGEMENT OF CRUCIBLES IN COKE-FIRED MUFFLE

directly between the two charged crucibles. Reference to Fig. 2 will make the arrangement clear.

All experiments performed on slags 1, 2, 4 and 5 were conducted in the electric furnace according to the first method described. Owing to the extreme

TABLE V.—THE DISTRIBUTION OF SILVER BETWEEN LEAD AND SLAG NO. 3 AT VARIOUS TEMPERATURES

Temp. C.	a	b	c	d	e	Average Ratio
780	0.0050	0.0064	41.1	6420	6180	
780	0.0075	0.0086	41.2	6240	6000	
780	0.0050	0.0064	41.2	6440	6190	
780	0.0075	0.0064	41.2	6440	6190	6140
837	See Table IV for complete data.....					3980
892	0.0150	0.0163	41.5	2550	2450	
892	0.0180	0.0159	41.3	2600	2500	
892	0.0150	0.0155	41.0	2640	2540	
892	0.0180	0.0155	41.0	2640	2540	2510
960	0.0180	0.0244	41.5	1700	1635	
960	0.0260	0.0242	41.5	1715	1650	
960	0.0180	0.0244	41.5	1700	1635	
960	0.0260	0.0244	41.6	1705	1640	1640
1045	0.0300	0.0370	41.6	1125	1080	
1045	0.0450	0.0390	41.6	1070	1030	
1045	0.0300	0.0358	41.1	1150	1110	
1045	0.0450	0.0370	41.1	1110	1070	
1045	0.0300	0.0400	41.3	1030	994	
1045	0.0450	0.0386	41.4	1070	1030	1050
1143	0.00	0.0555	36.5	658	634	
1143	5.25	0.0552	35.4	641	616	625
1173	0.00	0.0659	38.7	588	565	
1173	5.25	0.0654	37.4	572	550	558

Explanation of table:

a = mg. of silver per g. of slag before lead was added.
b = mg. of silver per g. of slag after stirring with lead.
c = mg. of silver per g. of lead-silver alloy at end of experiment.
d = ratio of equilibrium concentrations = c/b.
e = ratio of concentrations corrected for losses incurred during assay of slag.

fluidity of slags No. 1 and No. 2 and to their tendency to rapidly corrode the crucibles, experiments with them were attempted only at the lower temperatures. On the other hand, slags No. 4 and No. 5 could be worked with only at the more elevated temperatures, because of their high formation temperatures and high viscosities. As has been noted above, slag No. 3 possessed properties most favorable to investigation over a considerable range of temperature. Hence the experiments with it are more complete than in the case of any of the others. Results of experiments on slags 1, 2, 4 and 5 are collected in Table VI, wherein the letters at the heads of the columns have the same significance as in Table V.

One of the crucibles contained the reagents necessary to produce 175 g. of slag No. 3. The charge was allowed to fuse, and, when the formation of the slag was practically complete, 25 g. of a silver-lead alloy containing about 920 mg. of silver was dropped into the crucible. The alloy was added in the form of filings. The other crucible contained the same slag forming constituents as the first, but in addition there were present 28 g. of argentiferous litharge and enough argol to produce a 25 g. lead button. The silver present amounted to about 920 mg., and it had been originally added to the litharge in the form of a silver nitrate solution. The charge in the second crucible was allowed to fuse as if it were a regular assay. It is evident that in these two charges the initial conditions were not the same. In the first case the slag had no silver at the start, so silver passed from the lead to the slag after the addition of the alloy. In the second case all of the silver was present at the start as nitrate or oxide, from which condition it had to be reduced in order to alloy with the lead. Hence the lead had to remove some silver from the slag as it generally has to do in the ordinary assay.

After remaining in the furnace for about 70 minutes the crucibles were removed and samples of slag were decanted from the lead and assayed as usual. The lead buttons were allowed to freeze in the crucibles, after which they were broken out, weighed, and cupelled with checks to determine the amounts of silver present.

In applying this method the most uncertain factor is the temperature, the regulation of which is not so readily accomplished in the coke furnace as in the electric furnace. But by careful firing it was possible to secure temperatures so uniform that the thermo gage reading indicated a rise in temperature of less

than 12 deg. C. during the last 30 min. of the heating. The temperatures specified correspond to the readings taken just before the muffle was opened to pour the crucibles.

The average ratios of the equilibrium concentrations given in Tables IV, V and VI have been plotted to scale with their corresponding temperatures in Fig. 3. In this figure there is also shown a curve representing probable values of the distribution ratio of silver between lead and pure litharge at various temperatures, the position of this curve having been calculated from the observed data by a method of extrapolation, which will be explained later.

TABLE VI.—THE DISTRIBUTION OF SILVER BETWEEN LEAD AND SLAGS NO. 1, 2, 4 AND 5, AT VARIOUS TEMPERATURES

Slag Temp.	C.	a	b	c	d	e	Average Ratio
1	837	0.0150	0.0193	42.8	2220	2140	
1	837	0.0200	0.0203	43.7	2150	2060	
1	837	0.0150	0.0199	42.7	2140	2060	
1	837	0.0200	0.0204	43.3	2120	2040	2080
1	892	0.0200	0.0291	43.5	1490	1430	
1	892	0.0400	0.0280	42.8	1530	1470	1450
2	837	0.0150	0.0159	41.5	2610	2510	
2	837	0.0250	0.0155	41.8	2700	2600	2555
2	892	0.0200	0.0240	42.0	1750	1680	
2	892	0.0350	0.0252	41.6	1650	1590	1635
2	960	0.0250	0.0375	43.2	1150	1110	
2	960	0.0500	0.0400	42.1	1050	1010	1060
4	892	0.0050	0.0100	41.0	4100	3940	
4	892	0.0150	0.0096	41.1	4290	4120	
4	892	0.0050	0.0104	40.8	3920	3770	
4	892	0.0150	0.0112	41.0	3660	3520	
4	892	0.0050	lost	
4	892	0.0150	0.0098	40.8	4160	4000	3870
4	960	0.0100	0.0147	41.0	2790	2680	
4	960	0.0200	0.0151	40.7	2700	2600	
4	960	0.0100	0.0150	41.4	2760	2650	
4	960	0.0200	0.0152	41.4	2720	2610	2635
4	1045	0.0200	0.0258	40.8	1580	1520	
4	1045	0.0400	0.0269	40.8	1520	1460	1490
5	960	0.0050	0.0098	41.1	4200	4040	
5	960	0.0150	0.0100	41.1	4110	3950	3995
5	1045	0.0150	0.0157	40.8	2600	2500	
5	1045	0.0250	0.0168	41.0	2140	2350	2425

For explanation of a, b, etc., see Table V.

The Effect of Temperature

The marked effect of temperature upon the ability of the slags to retain silver in the presence of metallic lead is well illustrated by the curves of Fig. 3. For example, at 800 deg. C. a gram of lead-silver alloy in contact with slag No. 3 will contain about 5200 times as much silver as will a gram of the slag; at 1150 deg. C. this ratio is only 600 to 1. Within a temperature range of 350 deg. the ability of the slag to retain silver in the presence of metallic lead experiences more than an eight-fold change. Changes in the concentration ratios with temperature in the case of the other slags are correspondingly great. In view of the great effect of temperature upon the distribution of silver between the metal and the slag it is evident that close regulation of the temperature during an experiment is essential, if reliable results are to be secured.

(To be concluded)

The National Association of Manufacturers held its annual convention at the Waldorf-Astoria, New York, on May 15, 16 and 17. About 500 delegates were present, representing 4000 industrial concerns throughout the country. It was declared that the wave of prosperity in this country is increasing rather than abating. A resolution was adopted that a plan of organization be formed, representative of as many industrial organizations as possible, which may agree on certain definite principles and may express its opinion with respect to government measures and policies.

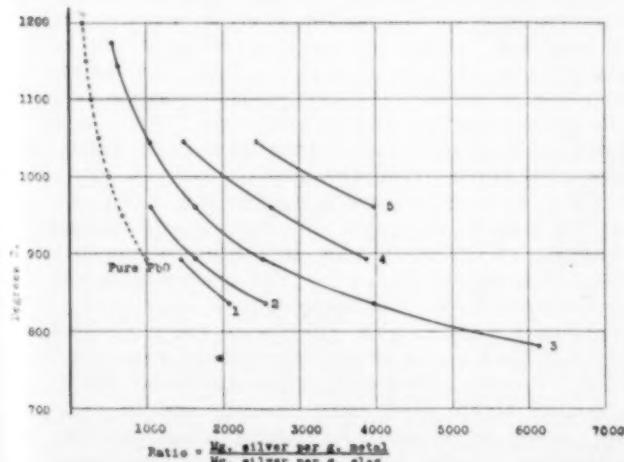


FIG. 3—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER-LEAD ALLOYS AND SLAGS AT VARIOUS TEMPERATURES

The Distribution of the Charge Column and of the Ascending Gas Column

BY J. E. JOHNSON, JR.

Granting that the foregoing articles have given a fair idea of the many actions which go on inside the furnace, and the fundamental laws by which they are limited and controlled, with methods for calculating the burden desired for each given case, it might be thought that the problems concerning the operation of the furnace were all solved. It would be nearer true to say that their solution was just begun.

The question on which the practical operation of the furnace depends more than any other is the distribution of the raw materials in the top of the furnace, and while far less important the question of distribution of the gas in the different zones of the furnace is a matter of great moment, the two being obviously interdependent to some extent.

We have discussed the first of these questions at some length in the article on filling the blast furnace, and the second in the article on mechanical principles. It may be as well to confess frankly at the beginning that it is far easier to handle these two questions from those points of view than it is from the complex one of operation.

As I have emphasized several times before, the prime desideratum is that each particle of the burden shall have a uniform exposure to gas and to heat in its journey down through the shaft and bosh into the hearth. The question is how to secure this condition.

Distribution and Control of the Gas Column

Leaving for the present the more difficult question of distributing the stock let us consider that of controlling the gas flow. This may be considered from two points of view: first, that of conditions in the lower part of the furnace within the range in which penetration is effective; second, the upper regions of the furnace, roughly speaking, the shaft.

THE DISTRIBUTION OF THE BLAST IN THE HEARTH AND BOSH

In the first region we have two factors of control. One is the penetration itself, the other the density or openness of the charge column in its different portions from the center outward. Reference to Figs. 1, 2 and 3, in the article on mechanical principles (issue of January 1, 1916, page 41) shows that the effect of improper penetration, whether too great or too small, is gradually smoothed out by time and flow until at a certain distance from the tuyeres the distribution of the gas is no different with bad penetration from what it is when good. Obviously the distance in which this levelling action occurs is important. The experimental difficulties in making determinations of this point would be vast, not to say insurmountable, we have therefore to guide us only our general knowledge of furnace operation.

I have often heard of attempts to control the action of the gas by penetration at levels far above the top of the bosh, but as far as my own observation goes I have reached the conclusion that the top of the bosh is about the limit of the height within which changes in the action of the furnace may be produced. We do know, however, that they can be produced up to this level because we know that we can regulate the tendency of the furnace to build or scour on the bosh even quite close to the top of the latter by altering the size and length of the tuyeres, and if a scaffold forms on the bosh we know that we can generally remove it by proper alteration of the penetration. On the other hand I have known of at least one case where a scaffold was formed

on the lower part of the bosh by excessive penetration, driving the gas column to the center of the furnace and allowing the bosh walls to remain so inactive that slag and other materials built on them so as almost to shut off the passage of the gas altogether.

It is important to notice in this connection that an action which is started by the gas itself may develop in such a way as to increase that action. Thus, if the gas is passing too much to the center and a scaffold begins to build on the walls just above the tuyeres its tendency is to throw the gas still more strongly to the center and thereby favor still further building on the walls, this condition continuing until the furnace can no longer operate, as in the case mentioned.

On the other hand I have already mentioned the case of a furnace with very deficient penetration in which the charge column built up like a cone in the center of the hearth and filled the latter up until there was nothing left except a narrow ring around the outside. In that case the formation of a "dead-man" in the center of the furnace naturally tended to throw the blast back more strongly against the walls and so to cut them away more actively, with the result that the lining of the hearth on this furnace was almost totally destroyed after a comparatively short campaign, and breakouts in consequence were numerous.

It is perhaps too broad a statement to say that improper penetration brings about conditions which tend to increase the very tendencies that produced them, and so continually get worse, but we may safely say that this is the result in many cases, and for this reason, as well as on its own account, correct penetration is of the utmost importance.

IRREGULAR PENETRATION

In all that has gone hitherto we have assumed that the penetration was alike at all the tuyeres. But this is unfortunately not true, and differences in the quantity of wind blown into the tuyeres in different sectors of the furnace have been responsible for some very unsatisfactory furnace work whose cause was to the last degree obscure and hard to find. In ordinary practice the hot blast main strikes the annular bustle pipe around the furnace on a truly radial line, and in that case if there is a reasonable length of straight main next the bustle pipe the blast naturally divides itself evenly around the two sides of the latter, and we have symmetry of distribution on each side of this principal diameter, but in regard to the diameter at right angles to it this is not the case. The velocity of the blast in the hot blast main is exceedingly high, and the surface friction being quite large the drop in pressure per unit of length is far greater than in most air piping, so that the pressure on the side next the inlet is on the average appreciably higher than that on the opposite side, and the pressure at the first two or three tuyeres next the inlet is considerably higher than those in the same semi-circle but further from the inlet.

This condition in itself is bad and the remedy appears at first sight to be simple. We need only to increase the diameter of the bustle pipe until the pressure is virtually the same all around it. But to this there are two objections. First: the bustle pipe is enormously large and heavy even as now constructed for high velocities and would of course be correspondingly worse for lower ones. Second: the remedy under conditions which have prevailed at all plants until recently, and at most even yet, would be of short-lived benefit because the dust picked up by the blast out of the stoves is carried through the gas main and into the bustle pipe. Near the inlet the velocity is high enough to keep it moving, and instead of settling it is carried out the tuyeres, but

in the portions of the circle more remote from the entrance the velocity having become proportionately diminished, the dirt soon settles and gradually builds up in the pipe, reducing its area down to that at which the velocity is sufficient to prevent more dust from settling.

In some cases the conditions are even worse than this. The hot blast main is brought into the bustle pipe not on a radial line but eccentrically. This makes a sort of back-water of the region just back of the inlet (see Fig. 1) because the blast owing to its high velocity cannot turn the sharp corner so as to supply this region properly and therefore its blast supply, at least in part, has to travel all the way around the circumference of the bustle pipe. This, of course, greatly exaggerates the conditions described for the symmetrical arrangement, the region immediately in front of the inlet receives a decided over-supply of blast, and the region just behind it a correspondingly deficient one.

At least one case is on record in which certain furnaces having the hot main about three feet off the center of the bustle pipe (not enough to be visible to the naked eye without close observation) ran fairly well on foundry iron but very unsatisfactorily on basic iron. It seemed impossible to keep the sulphur low enough when the silicon was within the proper limits. Finally the trouble was traced to the unsymmetrical arrangement

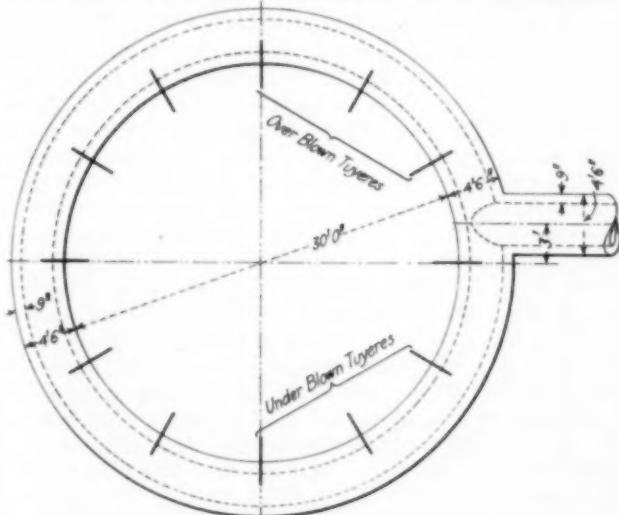


FIG. 1. EFFECT OF HOT MAIN ENTERING BUSTLE PIPE UNSYMMETRICALLY

and the tuyeres just in front of the inlet were changed to a smaller size so as to prevent the higher pressure of the blast in this portion of the bustle pipe from driving an excess of wind through these tuyeres. This cured the trouble absolutely and the furnace thereafter gave entirely satisfactory results on basic iron.

Since the realization of the conditions brought about by this case much more attention has been paid to this subject and now in some cases it is the practice to use smaller tuyeres next to the inlet even on furnaces with symmetrical bustle pipe, and this practice is probably well founded. It would seem legitimate also to increase the tuyeres on the far side to a corresponding extent, but this is commonly not done.

Just what is the mechanism by which the action of the furnace is upset under these conditions we do not know. Two or three theories could be advanced, some of which would be exactly opposite to others. But we do know that the prime condition for proper furnace work is absolute and complete uniformity of conditions on all sides of the furnace, and that such a condition as this, violating fundamentally that requirement, must produce bad results.

I incline to the belief that the action in such a case is somewhat as follows: We know to a certainty that if the furnace as a whole be blown to its proper capacity, the region receiving the excess of air must be overblown. This means that the stock is allowed less time than it should have for complete reduction and this in turn probably means a scouring slag which leads to high sulphur. The more rapid rate of driving in this sector leads to a more rapid descent of the charge in that sector, and owing to the greater mobility of its lumpy portion this means that the lumps tend to be drawn toward this zone of the furnace. It is as though the layers of charge which should normally be horizontal were tilted down on this side so that the lumps tend to travel this way. These require more time for their complete reduction than do the fines, therefore tend to exaggerate the raw condition of the iron produced in this sector, and being more open and permeable to the gas they tend to increase the velocity of the gas in this sector and therefore to exaggerate the conditions which originally started the irregularity.

In other words, we have here again a case in which the tendency probably is for the results of a certain condition to react on the causes of that condition so as to make it worse, the evil being thus self-intensifying. It will be seen therefore that it is not only important to have the areas of all the tuyeres correct to give the proper penetration but it is important to have the total area so distributed among the different tuyeres as to compel an equal quantity of blast to enter the furnace in each sector.

EFFECT OF STOCK DISTRIBUTION ON GAS FLOW IN BOSH

Turning now to the second factor in the control of the gas column in the lower portion of the furnace we have to consider the varying density of the charge column. This is a subject concerning which we know but little. I shall presently describe a case in which a dense impervious core was produced by the filling, and this undoubtedly descended into the bosh. But rodding tests at the tuyeres did not show any conclusive evidence of deficient penetration at that level, and rather drastic variations of tuyere diameters to try the effect of increasing penetration upon the dense core did not yield any results of value. This seems curious; it would be foolish to try to give a reason for so obscure and complex a phenomenon, but it may be suggested that the dense core in that portion of the charge in the shaft being made up almost entirely of ore and flux, as we know it to have been constituted, was melted by the expenditure of much extra coke somewhere up in the bosh and ran down into the hearth. This then would leave the coke free to fill the space vacated and would produce the condition of comparatively uniform penetration which we found.

Claims have often been made as to the effect on the bosh walls of changes in the filling, that they built up with certain kinds of filling and scoured off with others, etc. I have never had any experience in which I could identify these conditions myself, but they may exist. My own feeling is that penetration is the predominate factor in gas distribution up to the top of the bosh, and above that stock distribution is the controlling, almost the sole factor.

THE EFFECT OF STOCK DISTRIBUTION ON GAS FLOW IN THE SHAFT

In the article on filling the furnace we have seen the necessity for distribution symmetrically about two or more equally spaced axes, and this symmetry must not be only quantitative but qualitative. It is not sufficient to have the same total amount of material in each sector of the furnace, we must have equal quantities of each

of the raw materials in the charge, and further than this we must have as far as possible equal quantities of each size of the different kinds of raw materials.

I have endeavored to emphasize this so strongly in the chapter mentioned that perhaps no additional stress need be laid upon this point here. But these requirements alone are not enough, the distribution of the different sizes of materials in the proper position radically is as important as is a symmetrical distribution circumferentially.

THE EFFECT OF THE SIZE OF THE BELL

The effect of the wall in increasing the voids in the material adjacent to it was also pointed out in the article on filling, and we know from the considerations there given that at least a considerable portion of the fine material should be placed against the walls by the charging operation. In regard to the quantitative effect of the further factors which control in this important and complicated matter we have no information whatever. We know that a bell large in proportion to the stock line will distribute most of the fine material against the walls, and we have already seen that this is desirable up to a certain point, but if the bell be made too large the effect on furnace work is not to improve it further, but to make it distinctly worse. We do not know precisely why this is. We may well imagine, however, that the placing of too great a proportion of the fine material immediately adjacent to the wall cuts off the currents of gas to so great an extent that that portion of the charge is not kept active, and this leads as we know by experience to building on the walls, consequently to formation of incipient scaffolds, and all the evils which they bring in their train.

Of course, if we make the bell too small then the fine material is deposited too close to the center of the furnace, the lumpy and more open portions of the charge roll to the walls, by which their natural voids are increased, as we have seen in a previous article, almost 100 per cent, and the result can only be that the gas rushes violently up the sides of the furnace, leaving a column of more or less dead material up the center which is deprived of its proper proportion of the reducing action of the gas and so descends into the hearth in a raw condition, while on the other hand the extreme rapidity of action produced next the walls by the excessive gas currents makes the lumpy portion of the charge travel too fast, which has two bad effects. First: the outer portion of the column descending more rapidly than the inner tends to increase what might be called the reversed-crater action next the walls with the result of drawing a still greater proportion of the lumpy material to that region, and so increasing the objectionable action which gives rise to these conditions. Second: the lumper portions of the charge need more time for their complete reduction than do the finer ones, hence the larger lumps, in spite of the excess gas to which they are exposed, tend to reach the hearth improperly reduced because not allowed sufficient time for complete reduction.

It becomes plain, therefore, that there is a satisfactory explanation for the fact, which we know so well by experience, that to do good work the stock distribution must not only be symmetrical, but the size of the bell must be such as to put the proper proportions of fine and coarse material in their proper radial positions.

DIFFICULTIES OF EXPERIMENTS ON MODELS

It might be thought that it would be simple to determine experimentally what size of bell and other top arrangements would give these desired conditions, and such attempts have been made on scales of varying sizes dozens of times. They are open to two objections.

First, it is very difficult to duplicate in an experimental way either full size or on reduced scale the actual conditions which prevail at the top of the furnace. To begin with we have no means of causing the regular and uniform settling of the charges as we deposit them in our experimental apparatus, and if we do not produce uniform settling we cause a cratering action in one or another portion of the top surface which is likely to distort or destroy the correctness of the results obtained with subsequent charges. There are, of course, many other operating and practical difficulties in the way of such experiments, not the least of which, if they be full size, is the expense.

Second, granting that we can determine correctly with an experimental apparatus the results that will be obtained with any given design, how are we to select the one which will produce the best results on the furnace?

On one occasion the general superintendent of a certain plant declared to a visiting furnace man his intention of constructing a full size model of his furnace top and experimenting on it with all kinds of distribution, and then at the end of the experiments selecting the one which he liked best. The visiting furnace man asked how he knew that the furnace would like best the system that he liked best. No answer was forthcoming, and from the nature of the case it is almost obvious that none could be. The laws affecting symmetry of stock distribution, etc., we understand quite well; they are fundamental. But having that foundation, there remains a great superstructure of details to be built, for the design of which we have not, and seem likely never to have, any simple or inductive method; nothing but the slow and tedious process of trial and error, varying one detail at a time, keeping all other conditions constant, is sufficient for the solution of so difficult a problem.

Add to this the almost infinite difficulty of keeping all the other conditions constant under such complex conditions, and it becomes easier to understand why we have as yet so little knowledge even of the empirical kind to guide us in these matters. General experience is sufficient to give us a fair working start and reasonably good results. Anything beyond that must be obtained by each individual furnace man to suit his own conditions.

THE EFFECT OF SIZING ON MIXED MATERIAL

This is a subject to which too little attention has been paid. Its importance was first pointed out, so far as known to me, in a paper by Mr. Frank Firmstone.

The reasoning is very simple. If we take a quantity of spheres, all of the same size, we can quite easily figure the percentage of voids between them, as has already been done in an earlier article, and this is a perfectly definite mathematical proportion. But if we started off with, say, 3-in. spheres, we could insert into the larger interstices of these smaller spheres, say 1 in. in diameter, and into the interstices then remaining still smaller ones, say $\frac{1}{4}$ in., and into the interstices still remaining smaller ones, say $\frac{1}{16}$ in., and so on down. The size to which we should descend in the individual case is controlled by the size of the raw materials with which we have to deal. Now supposing that we have a mass made up of heterogeneous spheres with all the interstices filled with the smallest size of spheres we have available. Suppose that we put the whole mass over screens which separate it into their original uniform sizes? Each of these sizes would contain, of course, the fixed mathematical proportion of voids above given, no matter how small the spheres might be, and the gross volume of the sized material would be far larger than

the volume of the mixed mass of heterogeneous spheres, in which obviously the percentage of voids would only be a small fraction of what it was in each of the sized varieties.

What is accurately and mathematically true of spheres is true in a general way of irregular material, particularly if that irregular material be of a uniform kind, and have, therefore, an approximately similar shape, irrespective of its size, which is roughly the case with the different kinds of raw material, so that for any considerable mass of a given irregular material the same general laws hold as for the mass of spheres.

Remembering now that one of our fundamental laws for proper operation of the furnace is that each portion of the charge column must be exposed to the same quantity of gas, and considering the enormous effect of permeability on the passage of the gas currents, the practical effect of this general law becomes obvious. If we wish to make the charge column more permeable in any given portion we must have recourse to sizing of some kind, and if we desire to make the charge column as a whole more permeable sizing of all the fine portions of the raw materials is our only recourse.

Working along this line I made some experiments several years ago whose results are indicative of the great effect which may be produced in this way. We made a heavy wooden box containing 1 cu. yd., and filled this with the crushed hard ore of the Birmingham district, crushed to go through a 3-in. ring. We then cut this cubic yard of ore into three sizes, over one screen, and over and through another. The first attempt gave portions of very different sizes. On the second attempt we used screens of $\frac{1}{8}$ -in. and 5/32-in. mesh, and these two screens cut the whole mass into three almost equal portions.

The specific gravity of the solid ore was determined in the laboratory, and from the weight of the original cubic yard we could easily determine what its volume unbroken would have been. The difference between this and the cubic yard gave its voids in the mixed condition. After screening, the volume of each of the three portions was determined by putting it back in the cubic yard box, leveling its top carefully, and measuring the depth. [This is very important, because if the volume of the portions be determined in a smaller box, the wall effect, that is, the increase in the voids next to the walls, for the reason already pointed out, is so great that the results are entirely distorted and worthless.]

By adding together the volume of the sized portions we obtained the volume of the original cubic yard in its sized condition, and deducting from this its calculated volume in the solid condition we obtained the total voids in the sized ore. This was increased 45 per cent over the voids in the original mixed ore. The detailed results are shown in Table I. The effect of such an increase in the percentage of voids on the permeability of the charge could not fail to be very marked. Unfortunately, we were unable to carry out any experiments on the use of such sized ore on the furnace itself, though the conditions under which it operated gave every reason to hope for substantial benefits.

In more recent years John N. Reese has made many sizing tests of Lake Superior ores entirely independent of the work done by me, and has found that precisely the same laws hold in all fine Mesabi ores as in the coarse hard ores of the South. The difficulties, however, of sizing in the case of such material as Mesabi ore are almost insuperable from the practical point of view, and it seems unlikely that we shall ever see a practical application of these laws in the case of such exceedingly fine material.

There is, however, one practical application of these

Table I.—Data of Screening Test on Birmingham Hard Ore

Specific gravity (laboratory)	3.45
Coarse through 3-in. ring, Over $\frac{1}{8}$ -in. mesh (made from No. 9 B & S wire, 1 in. center to center).	
Middlings, Under $\frac{1}{8}$ -in. mesh over 5/32-in. mesh (No. 5 B & S wire $\frac{1}{4}$ in. center to center).	
Fines	Under 5/32-in. mesh
Weight of 1 cu. yd., actual measure of crushed unscreened ore,	3852.5 lb.
Weight of 1 cu. yd., solid ore (from specific gravity)	3805.0 lb.
Volume of 3852.5 lb. ore if solid	17.92 cu. ft.
Voids in one cu. yd., mixed crushed ore	9.08
	27.00
Void in per cent of total volume	33.7
<i>After Screening.</i>	
Coarse	32.9
Weight in per cent of total	33.0
Weight in pounds	1271.5
Cubic feet of solid ore	5.91
Measured volume of crushed screened ore, cubic feet	10.25
	10.92
	9.92
Total volume	31.09
Volume of ore solid as above	17.92
Voids in crushed screened ore, cu. ft.	13.17
Per cent of voids	42.4
Average per cent voids in screened ore = 42.4	46.0
Volume of voids per given weight of ore, 13.17 cu. ft. in screened ore as against 9.08 cu. ft. in unscreened, or an increase of 45 per cent.	38.4
This last is evidently the important consideration for practical purposes.	

principles which I believe could be made much more frequently than it now is, and that is to abstain from mixing ores of different sizes with the idea that the coarser would loosen up the finer. The only result which this can possibly have is to cause the finer to obstruct the coarser without benefiting itself, and if ores of different degrees of fineness are to be charged in the same furnace they should be charged separately, not even in the same round, if this can possibly be avoided, because the more they are mixed the worse the results must necessarily be. There may be one case in which it is justifiable to violate this rule. When the main portion of the charge consists of a fine sandy ore, and a minor portion of the charge is of a lumpy or plastic nature, the latter portion may be charged first separately, so as to make a blanket over the top of the coke and prevent the fine ore from running down through the fuel. The loss of porosity in this case is more than compensated by preventing contact between fine ore and fuel, but I wish to reiterate my conviction that, generally speaking, where two ores of different coarseness are to be charged the more widely separated they can be the better will be the results on the furnace. If I had two furnaces and a total ore supply made up of one-half very fine and one-half coarse, I should be very much tempted to use all the coarse in one furnace and all the fine in the other. Perhaps alternate charges of each kind would be as good, but certainly either of these would give vastly better results than mixing the fine and coarse in the same charge.

THE SIZE OF THE COKE CHARGE

This is a point of much importance, and in this, as in so much else that concerns the filling of the furnace, we have only empirical knowledge to guide us. Mr. E. A. Uehling pointed out several years ago that the effect of the layer of ore on the gas rising through it was an oxidizing one, while the effect of the layer of coke immediately above was a reducing one, and that as we desired the maximum of reduction by gas, it was very important not to have the fuel and ore charged in a mixture, but to keep them in separate layers, and that, moreover, the effect of the separation was greater the thicker were the individual layers. This is simply another phase of the fact which I have already attempted to emphasize, that the more points of contact of ore with coke the greater the solution loss, and the poorer the economy, and in principle this is entirely correct.

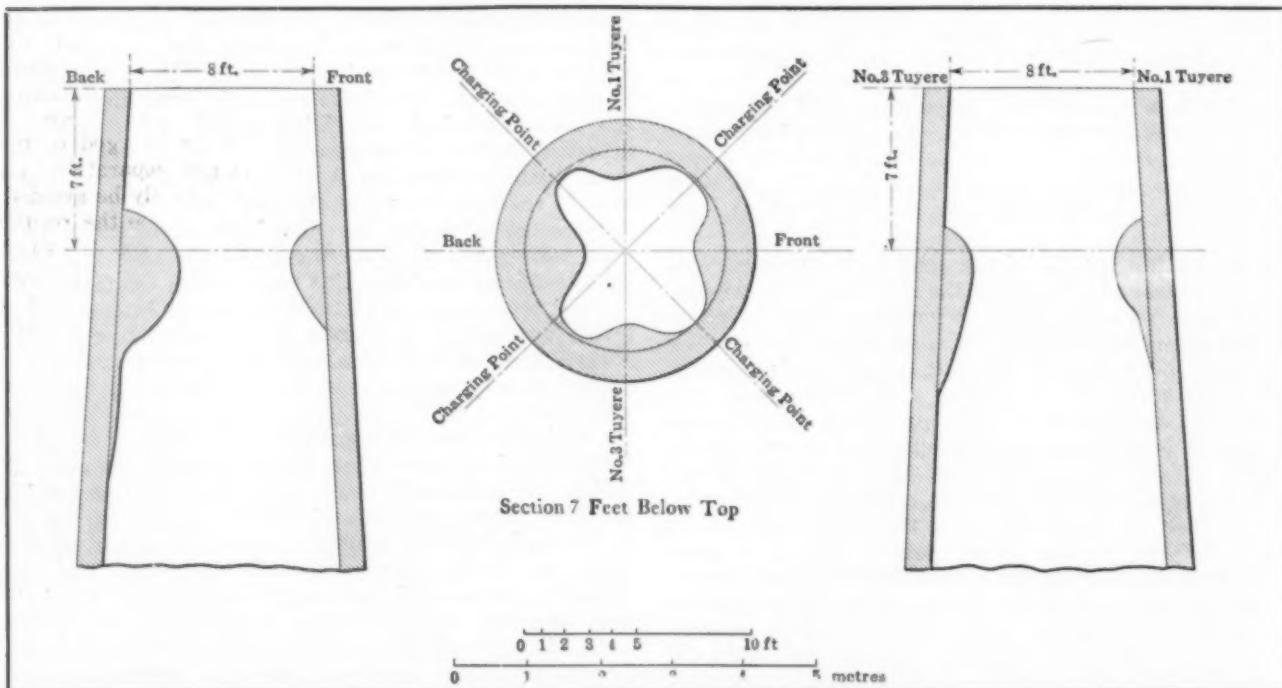
There is obviously a limit, however, since there must be a certain intimacy of mixture between the ore and the coke which is to perform the final reduction upon it in the hearth, and it is presumably this factor which sets a limit to the size of the fuel charge which we can use. That there is such a limit has been determined by the experience of many furnace men. My own experience covers one such case whose results were unmistakable. In order to obtain more symmetrical filling at a charcoal furnace with a very small stock line diameter, and using very large barrows, I wished to use four barrows at a charge instead of two. A first attempt was not successful because the top as it stood was not adapted to correct dumping at four points, but on a subsequent blast, having redesigned the top so as to permit absolutely symmetrical dumping at four points, I started the furnace off with a four-barrow charge. After a week or so of operation in which the fuel consumption remained far higher than it should, I became convinced that the thickness of the charge layers might have something to do with it and changed to a two-barrow charge, obtaining symmetry by alternating the dumping positions on each alternate charge. The result was immediate. The fuel consumption of the furnace at once dropped 5 or 6 per cent, and its work became more sat-

isfactory for reasons of simplicity and easy construction by a single outlet on one side communicating directly with the downcomer.

Many furnace men have felt that this construction was open to criticism because the path of the gases originating immediately under the gas outlet is shorter and therefore easier than the path of the gases on the opposite side, and in less degree at intermediate points, and they have felt that this produced a lack of symmetry in the gas current which was likely to affect adversely the working of the furnace. Many furnaces, however, ran successfully with this construction, and other furnace men came to believe that this was a theoretical point of no practical importance.

As the rate of driving has increased, however, the effect of this difference in resistance has become more marked, and an increasing number of furnace men have come to believe that the single gas outlet was wrong, not only in principle but in practice. Fortunately this is a subject on which we have evidence of such overwhelming weight that the matter need never again be considered open for discussion once the evidence is considered.

The brown ores of Virginia and Tennessee contain small quantities of zinc, which is vaporized by the heat



FIGS. 2, 3 AND 4. ZINC RING (FIRMSTONE)

isfactory in all respects. From such data as are available it seems that the average thickness of the coke charge in a 22 by 90-ft. furnace is about 2 ft., and this appears to be more or less established practice with furnaces of this size on Lake Superior ores. For furnaces of smaller size it is probable that the thickness of the fuel bed for best results remains about the same and that, therefore, the weight of the proper coke charge diminishes in proportion to the diminished area (not diameter) of the stock line.

THE EFFECT OF THE LOCATION OF THE GAS OUTLET ON THE DISTRIBUTION OF THE GAS CURRENTS THROUGH THE FURNACE

In the article on filling it has been pointed out that the old practice was to use the center out-take for the gas, thus securing perfect symmetry for the gas current from all portions of the furnace. This was suc-

cessful for reasons of simplicity and easy construction by a single outlet on one side communicating directly with the downcomer.

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of the charge, and since zinc oxide is one of those solids which passes directly from the solid to the gaseous condition, and vice versa, without passing through the liquid state, this rises through the furnace with the gas until it meets the cold entering charge and the cool top walls of the furnace, when it solidifies. That portion which solidifies on the charge itself is carried back into the furnace and again sublimed, but that portion which solidifies against the walls builds there in solid form. It grows in concoidal layers and forms a material of great strength and toughness, especially at the temperature prevailing a short distance below the stock line, where it generally deposits, some 800 or 900 deg. Fahr.

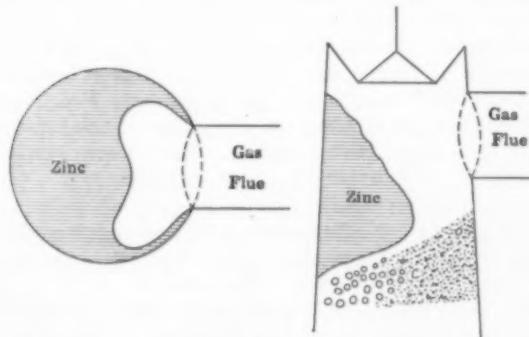
Mr. H. Firmstone in a paper before the American Institute of Mining Engineers in 1876 described the action of this material in the furnace at Longdale, which was equipped with the center out-take and double bell. His drawings of the shape of the zinc ring formed

found on blowing out, made from very careful measurements, are reproduced in Figs. 2, 3 and 4. The approximate symmetry of the formation about two axes at right angles is obvious. The thin places in the ring are immediately under the dumping points, because most of the fines of the charge remaining at those points obstructed the gas currents, while half way between the dumping points were the coarser portions of the charge which permitted a more active gas circulation and consequently the deposit of more zinc oxide.

These results were confirmed by all the subsequent experience at these furnaces. The symmetry was not always so marked, but was in general greater in proportion as the furnace was more regular, but any irregularity was what might be called self-intensifying, because a greater growth of zinc ring meant a greater distortion of the charge and more obstruction of the fines, which were crowded over and could not roll back under the obstructing zinc, while the coarse could and did do so, and thereby produced a more open charge condition under the obstruction and so brought a greater portion of the gas current to that section of the furnace, and thereby promoted a still greater growth of zinc formation.

This effect was so serious and the detrimental action on the regularity and fuel economy of the furnace was so great that it became the custom to shut the furnace down for about forty-eight hours every six months and cut off the zinc ring with long steel bars, sledging them from the operating platform. Incidentally this job was including the removal and replacement of the top apparatus, of such severity and difficulty as to make one wish at least during those periods that he had chosen another occupation.

About twenty years later W. W. Taylor described in the *Iron Trade Review* the growth of zinc "ring" in a furnace filled with a single bell and provided with a single gas outlet on one side, this furnace being very hard-driven for its size. Mr. Taylor's drawings of this zinc formation are reproduced in Figs. 5 and 6. It will



FIGS. 5 AND 6. THE EFFECT OF A SINGLE LATERAL GAS OUTLET ON GAS FLOW AS SHOWN BY ZINC OXIDE DEPOSIT (TAYLOR)

be seen that the zinc formation started at a point exactly opposite to the downcomer opening, presumably because the smaller gas current, due to the longer path the gas on that side had to travel, permitted a greater cooling effect. The stock was forced to flow over the nose of the zinc formation toward the center of the furnace. The fines stayed where they fell in that position. The coarse rolled back to the wall underneath the zinc formation and induced a more rapid flow of gas to that side. Greater cooling followed the more rapid downward travel of the lumpy material and more zinc followed the greater upward flow of gas. Consequently, the deposit of zinc was bound to grow here and to work its way down the furnace as the cooling effect of the

coarse material descended further and further, until the lower end of the zinc formation reached down almost to the top of the bosh.

The furnace was working almost entirely on this side, and the other side was presumably almost dead. I have seen the same thing at Longdale in a less degree on several occasions. The zinc formation descended to the lowest level in the furnace underneath those points where the obstruction to the descending charge had been the greatest. Of course from this reasoning it is evident that once the zinc formation were started in this way with the single gas outlet it had no recourse but to grow increasingly worse. This, however, is not the most important lesson to be learned from this most instructive bit of furnace history; it is that the original zinc formation would never have occurred in the way it did in the first place if there had not been a decided lack of symmetry in the gas current due to the longer path on the side opposite to the single gas outlet, and I believe that all experienced furnace men will agree with me that the above constitutes an absolute proof that an unsymmetrical gas outlet is bound to lead to irregular distribution of the gas column relative to the charge column, and that while its effects are probably not so strongly self-intensifying as when zinc is present, nevertheless it offers possibilities of trouble, to avoid which no reasonable expense in construction should be spared.

THE EFFECT OF THE TAPPING HOLE AND CINDER NOTCH LOCATION ON THE GAS COLUMN

It has been contended by some furnace men that the drawing effect of removing the liquid contents of the furnace hearth in one direction or another toward the tapping hole or the cinder notch affected the gas distribution, and that this effect could be offset by a corresponding lack of symmetry in the location of the gas outlets, but I have never seen anything in my own experience to confirm this contention, nor have I been able to discover any reasoning which would lead to such a conclusion. The iron and slag are withdrawn from the furnace when the blast is on, and therefore when the conditions in the hearth and bosh are normal, which means when there is a state of violent activity throughout all those regions. Remembering that the (solid) coke in the bosh is so intermixed with slag and gas as to constitute the whole mass a liquid, it is difficult to see why it should not retain an approximately horizontal surface throughout all portions of these regions. Of course, the liquid concerned is to some extent viscous, and the tendency is for it to descend more rapidly in those portions where the flow lines are the shortest, and so during such periods there might be some effect on the distribution of the gas current, but it would not seem likely that this should be very marked.

On the other hand, the erosive action of the liquid flow must not be forgotten, and it is easily conceivable that a tendency to build up on the hearth or bosh walls might be prevented by the scouring of the liquid flow in the immediate vicinity of the tapping hole and cinder notch, while in regions remote from these points, there being no such scouring action, building up to some extent might occur and so in time produce a lack of symmetry sufficient to be important. For these reasons it is probably better not to have the cinder notch and the tapping hole too close together, and if physical conditions permit, a wise arrangement would be to have two cinder notches and to space these and the tapping hole at 120 deg. apart, using the cinder notches alternately. This, however, represents an ideal condition toward which we may aspire rather than a practical construction which we can ordinarily obtain.

THE EFFECT OF THE SIZE AND THE UNIFORMITY OF MATERIALS ON DISTRIBUTION

This is a subject which has had too little consideration in connection with the general subject of stock distribution, and the penalties which have been paid for failure to observe it have been both numerous and so severe in many cases as to be almost fatal to the success of the plant. It seems not generally to have been recognized that it is necessary not only to place the same amount of material in each sector of the shaft, but that the size of that material is of equal importance with the amount, and it is perfectly conceivable that careful tests might show the most absolutely uniform size of heaps on the bell (or on the stock line if examination inside the furnace be made before blowing in), but at the same time the distribution might be horrible because one section might be made up of lumps open and easily pervious to the gas, while all the others were made up of fine or even plastic material.

Of course, in regard to the coke this is only true to a limited extent, since with reasonably uniform handling the coke from one operation should be of reasonably uniform size, and this is a point which can under ordinarily favorable conditions be watched, and precautions taken to prevent variations in the coke, or if they must occur to insure that at least all one kind of coke shall not go to one side of the furnace and another kind to the other side.

But with the ore, particularly in the Lake Ore district, the conditions are very different. A certain percentage of old-range ores is generally, but not always, charged, and a much larger percentage, sometimes practically the whole charge, is made up of Mesabis. The ores from this range differ greatly from one another in degree, some of them being of almost impalpable fineness, and others containing a noticeable proportion of lumps, but as a whole these ores are of a sandy structure; that is to say, fine, relatively uniform and granular, while the great majority of old-range ores are either hard and lumpy, or else plastic, very much like ordinary clay except in color, the clay sometimes being interspersed with lumps, but the ores virtually never sandy.

It is obvious that the action of these ores in passing through the filling mechanism and through the furnace itself must be very different. The plasticity of some of them is so great that they will build up on almost any surface they touch, while others are almost as sharp and clean as crushed gravel. Some are so plastic that they will hold puddles of water for days, and, of course, when baked by the heat of the furnace tend to burn into hard, irregular lumps, while the sandy Mesabis, when dried by the heat of the furnace and agitated by the ascending gas currents, become almost as active as a liquid, and run almost as freely. The permeability of some of these ores to the gas current is obviously many times greater than that of others, while even with one kind of ore, if there be both fine and coarse produced in mining and crushing, the inevitable differentiation in size which takes place in dumping will divide a mass of this ore into two obviously different portions, one consisting of nearly all lumps, with very little fine, the other of a much greater portion of the fine with very little lumps. The difference in the permeability of these to the gas current is almost as different as if they were different kinds of ore.

If we start out, therefore, with a single kind of lump ore, the very action of dumping will produce a segregation, and we shall deliver two very different kinds of material into different portions of the furnace, of which one will probably contain two or three times as large a percentage of lumps as the other, with a correspondingly high percentage of voids, permitting free passage of the

gas, while the closely-packed fines in the other portion tend to obstruct the gas flow to a much greater degree. These conditions, of course, are repeated charge after charge, and in consequence we have perhaps all the lumps going down one side of the furnace, while all the fines and perhaps much more than half of all the material charged go down the other side.

This brings about a condition in the furnace which tends progressively to grow worse, because the freer travel of the gas through the coarse or open material causes all reaction on that side to be more rapid, and therefore causes the stock on that side to settle faster than on the side which receives the fines. This, of course, produces more or less of a crater in the top surface of the stock, and as the large lumps always travel the farthest, this means that the larger pieces to an increasing degree go into this crater while the fines stay around its rim. This increased segregation of the lumps causes still greater openness of the charge column at this point, and this in turn causes a still more rapid gas flow on this side with corresponding retardation on the other. The blast furnace being an apparatus which accommodates itself marvelously to unfavorable circumstances may not show by its output or fuel consumption the severity of the treatment to which it is being subjected, or only to a minor degree, though this is not generally the case, since bad filling is generally accompanied by extremely high fuel consumption and output poor in both quality and quantity. Moreover, such a condition can have only one result on the duration of the furnace campaign, no matter what its results may be on coke consumption and tonnage, and in this respect the results of such filling cannot be concealed for a very long time.

Its inevitable effect is to scour out the lining, not only by the predominance of the lumps, with their greater abrasive action on one side and their greater velocity, but also by the velocity of the ascending gas with its burden of abrasive dust. The lining is soon cut through, a fact which manifests itself by a hot spot on the shell within a few months or even within a few weeks of the opening of the campaign.

An excellent description and full data of such a case may be found in the paper of David Baker before the American Institute of Mining Engineers, Vol. XXXV, giving the results of the first campaign of the blast furnaces at Sydney, Nova Scotia, which were skip-filled and supplied with a burden of all lump ore.

The campaigns were not a matter of years, but scarcely one of months before the segregation, due to the use of the ordinary double bell top, without any attempt at circumferential distribution, had scoured through the lining to the shell in a rather narrow vertical zone, with the resulting necessity of blowing out and relining the furnaces, at an expense of many thousands of dollars.

Where fine ores are used exclusively it is obvious that such great segregation of the ore cannot take place, there being no coarse material upon which the segregating tendencies can operate. Consequently, with fine ores, if the quantity distributed to each sector of the furnace is the same, the results are not so serious and may be fairly satisfactory, because the absence of a difference in size eliminates the necessity for one of the fundamental conditions, viz., that in each sector the same proportions of lumps and fines, as well as the sum total of material, shall be charged.

It is a matter of painful recollection to those in the business during the period of the introduction of Mesabi ores that the furnace practice was notoriously unsatisfactory, particularly in the matter of life of linings, although at that time it was considered an achievement

to use 50 per cent of fine Mesabi, the remaining 50 per cent being Old Range ores, much of it of a lumpy or partly lumpy structure, whereas now 80 to 90 per cent Mesabi is common.

It has seemed to me probable that these Old Range ores, which were kept on to temper the admittedly bad effects of the fine Mesabis, may have been responsible for many of the lining troubles which were so frequent during that period. It is true that fine ores in themselves are very bad for reasons which I shall subsequently point out, but it is also true that if the burden is to be improved by mixing lumps with it, these lumps must be charged in such a way that an equal percentage of lumps and fines must go to every sector of the furnace. If they do not, the benefit due to the presence of the lumps, which is, I think, not nearly so much the opening up of the charge as has been believed, does not compensate for the fearfully bad effects of a segregation of lumps in one vertical segment of the furnace.

In confirmation of this it is certainly true that as the percentage of the objectionable Mesabi ores has risen, and that of the desirable lumpy ores has fallen, furnace practice generally has improved instead of growing worse, particularly in relation to life of linings. This is undoubtedly the product of many factors, and it may be a more or less academic question to discuss what those factors were, but I am firmly convinced that lumps not properly charged will not benefit a burden of fine ore, but will produce an additional detrimental action of their own, and I would rather run a furnace on an all fine ore burden entirely without lumps than I would on a mixture of lumps and fines if I could not absolutely guarantee the proper distribution of the lumps.

While matters are, as just stated, much improved now from what they were twelve or fifteen years ago, the question of stock distribution is still a very live one among the best informed furnace men, and the development of the furnace top is not yet at a standstill.

More than one furnace manager has told me that after the most painstaking experiments he has found it impossible to obtain a distribution with a plain double bell top which was good for more than one condition of weather, ore, etc. It is this conviction which has brought about the introduction of the rotating top or rotating distribution.

EXPERIENCE WITH THE REVOLVING DOUBLE-BELL TYPE OF TOP

A very unusual experience with furnace distribution a few years ago has imbued me with certain ideas in regard to stock distribution which are by no means held by all furnace men, so that I shall give the facts on which my conclusions are based.

At the time stated I was in charge of a plant of three furnaces, all equipped with the revolving double-bell type of top, the receiving hopper under the skips being a cone almost exactly as illustrated in Fig. 7. These furnaces, which were in the South, were operated on a

coke of only moderately good quality, and on an ore consisting entirely of lumps as mined, but containing a considerable quantity of fine as received on account of unsatisfactory methods of crushing, and their performance was exceedingly unsatisfactory. A fair tonnage could only be obtained from them at the expense of a high fuel consumption, a high blast pressure, and an exceedingly limited life of lining. The revolving top was fitted with automatic electrical recording pens, and it was the special duty of the burden clerk to check over these records to see that the skips were dumped in the proper sequence, that the receiving hopper was rotated to the proper angle, that the bells were manipulated after the proper number of skip loads, and that in general all details of charging were correctly carried out.

Within a few weeks after blowing in these furnaces would show a hot spot on the shell some 20 or 30 ft. above the mantle, not in any one position circumferentially around the shell, showing channeling, but indifferently at any point, and spreading from that point around until the furnace shell was hot in this zone most of the way around. The last thirteen or fourteen months of blasts, averaging fifteen or sixteen months, were made with a water spray on the shell to keep it cool. At the end of this period the furnace could no longer be operated and was blown out and relined completely.

As one of the furnaces was approaching the time set for it to be blown out for repairs its shell failed at a point some 40 ft. below the top, and a section some 8 ft. high by 12 long swung out like a barn door, letting all the material in the furnace run out down to that level. I took charge within a day or two afterward, and as there had been discussion as to the distribution in these furnaces it was decided to shovel out the stock remaining in the furnace, not from the bottom as is customary, but from the top, so that by cutting vertical faces across the stock in various directions we could obtain an accurate idea of the distribution which prevailed in actual operation, this being an opportunity which would not ordinarily arise once in a lifetime, the furnace having been in full operation up to the time of the shell failure, then immediately stopped and watered down.

The condition which this investigation revealed was astounding, and was one under which no one would have believed that a furnace could operate at all. The brick being all gone at the zone in question the furnace was about 24 ft. in diameter; the outside 4 ft. of this was taken up by a ring of coke entirely unmixed with ore and limestone, while the center was made up exclusively of ore and limestone with only an occasional piece of coke.

The assistant superintendent, Mr. W. L. Kluttz, who had been at the plant for several years under the previous administration, had maintained for some time that the furnaces were working with a core in the center, and had much valid evidence to support this view, but even he was not prepared for a confirmation of his opinion to this extent.

It seemed obvious that the bell was too small for the stock line, that the fine material dropping from the edge fell in a heap in the center, or at best in a small ring around the center, while the coke being larger traveled further and lodged entirely against the walls. Obviously, then, the thing to do was to reduce the size of the stock line or increase the size of the bell. To make sure we did both, and careful inspection of the stock surface when the furnace was being filled preparatory to lighting, made by going in under the bell, showed practically all the fines against the walls and nothing but large lumps of coke in the center. Air could be felt drawing up through the center freely, whereas no draft could be felt against the walls.

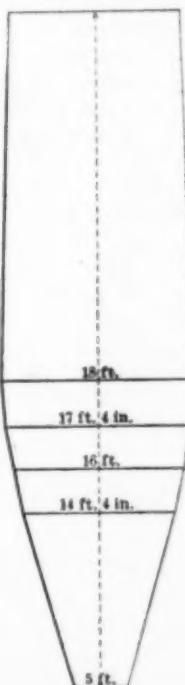


FIG. 7. BLAST-FURNACE OUTLINE

I felt convinced that we should obtain a different result and the furnace was blown in with high hopes, but after being in operation for six weeks without doing any better work in output or coke consumption than on the previous blast, and finally developing a small hot spot on the shell, we became convinced that we had not solved the problem.

Mr. Kluttz then suggested that the difference between that furnace and some other furnaces in the district, which were giving much more satisfactory results under precisely similar conditions, was that our stock distribution was in uniform rings while theirs was in heaps on the main bell, and he suggested that we so modify our top to secure this effect at least in part, which we could do without great expense.

The spout which we could put in was limited, and we were not sure that it would be long enough to secure approximately even distribution when opposite to the skip and when directly under it, but it seemed that nothing could be worse than the present conditions, so the change was made. No change of ore, coke, burden, blast, heat, or any other factor of furnace operation was made. At the end of the first day no change in the working of the furnace was visible. At the end of the second day the furnace without notice came up on 8 per cent silicon iron. It then became a matter of increasing the burden rapidly enough to bring the furnace down to normal foundry iron without danger of chilling it if the change suddenly went the other way. No such untoward event occurred, however, and at the end of five days from the time the change was made the furnace had gone from a daily production of 223 tons, with a coke consumption of 3300 lb., to a daily production of 285 tons and a coke consumption of 2750 lb.

The same change was made on another furnace which was supposed to be so nearly worn out as to be good for only about another month, but its work improved so greatly with the change that it was kept in for seven or eight months longer. As a result of this successful experiment the top of the next furnace which went out of blast was redesigned so as to convert it into the spout type of top somewhat similar to the Brown, but designed to secure the proper distribution both radially and circumferentially. This furnace ended only recently the campaign on which this modified top was installed, having run about forty-five months instead of the fifteen, which was formerly standard practice for those furnaces, and after making a record for tonnage and coke consumption such as no furnace at that plant had ever approached.

In view of these facts it is perhaps not surprising that in my judgment distribution in heaps on the bell is to be preferred to a distribution in rings altogether apart from the question of symmetry. Every furnace in that district fitted with the same type of top had given results precisely similar to ours, running with high fuel consumption, low output, high blast pressure, and short life. Other furnaces with the same type of top in other districts using very different types of ores had experiences so similar that a description of theirs might have been taken for ours. At the same time it must be admitted that in those districts where the ore is nearly all fine the contrast between ring distribution and heap distribution is much less marked in operation than it is in districts where the greater portion of the ore burden consists of lumps.

This experience agrees in a general way with experiences along a similar line at the time of the introduction of the closed-top furnace. I have been informed by Mr. Frank Firmstone [in private communication] that during the régime of the open top it had been considered good practice to spread the stock as smoothly

and uniformly over the top as possible. But when the introduction of the closed top brought about the use of the filling barrow, which necessarily dumped in heaps on the bell, the furnace work instantly and very generally improved. Why this should be so has never been made clear. I have never seen any explanation of the fact, which in itself is not very widely known. The only explanation that I have been able to make even tentatively is that when the ore is all dumped uniformly in rings the percentage of voids in it is much smaller than that which occurs in the lump portion when segregation of the lumps takes place. When the ore is dumped in heaps on the bell the tendency is for the lumps to segregate to some extent not only at the bottom of the hopper, but also along the sides of the piles made by dumping, and as the sides of these piles are practically radial this causes radial lines of more open stock to descend through the furnace, and thereby open up to the action of the gas the fines which may tend to gather there, thus preventing the formation of a column of more or less "dead" stock down through the center of the furnace.

That such a column may be formed, the facts I have already cited amply prove, and that by descending more slowly in consequence of its impenetrability to the gas this column tends to perpetuate itself by affording a lodgment for the fine material of the charge, while forcing the coarse to roll to the periphery is also true, and that the effect of dumping in heaps is to cause segregation of fine and lump, and thereby cause vertical planes of greater openness at the edges of the individual heaps is also true to some extent. But whether the comparatively slight change in the penetrability of the central column so produced is sufficient to cause the vast changes in the working of the furnace which I have seen at this plant and others cannot be considered as proven. Anyone who will advance a logical and satisfactory explanation of this action will lay the blast furnace profession under a lasting debt of gratitude.

Engineers in Preparedness Parade

Engineers played an important part in the impressive preparedness parade held in New York City on Saturday, May 13. The parade lasted approximately 12 hours and was composed of about 125,000 citizens representing a great number of professions. The engineers were led by the Naval Consulting Board, followed by the other engineers; mechanical, chemical, mining, civil, electrical, etc. There were between 200 and 250 in the chemical engineers' division and an equal number in the mining engineers' division.

Problems in Petroleum Industry

Dr. Raymond F. Bacon, director of the Mellon Institute of Industrial Research, lectured before the New York Section of the Society of Chemical Industry on the evening of May 19 on some problems in the petroleum industry in a very interesting and able manner, urging the need of more extended research. From the industrialist's viewpoint the great problem is flexibility in refining in order that only such products as are in special demand at the time may be produced, as at present gasoline and lubricating oils. The research was outlined on processes for the dehydration and desulphurization of crude oils and for the depolymerization of heavy oils, and especially on problems encountered in the chemical treatment of petroleum products and some present-day technical difficulties in refinery engineering. Petroleum will, like natural gas, form the basis of a chemical products industry which will be as distinct as the coal-tar industry of to-day.

The Extraction of Gasoline from Natural Gas by Absorption Methods*

BY G. A. BURRELL,¹ P. M. BIDDISON,² G. G. OBERFELL³

This paper deals with a method of extracting gasoline from natural gas by absorbing the gasoline in oil and subsequently separating the gasoline from the oil by distillation. The process is quite different from compression and condensation methods that have been used for a number of years for extracting gasoline from casing-head natural gas and has not heretofore been described in the literature.

The extraction of gasoline from casing-head natural gas by compression and condensation methods has assumed the proportions in this country of a large and lucrative industry, and placed in the market in the year 1914 about 43,000,000 gal. of gasoline. In addition there was used in marketing this casing-head gasoline at many plants an equivalent quantity of naphtha with which the casing-head gasoline was blended, thereby utilizing for automobile fuel and other purposes a very large quantity of naphtha that otherwise would have been unsuited for these purposes. A depression in the price of gasoline part of that year kept the production down to a certain extent. The increase for the year 1914 over 1913 was about 18,000,000 gal. For the year 1915 the production should be well in excess of 75,000,000 gal., and in 1916 well over 100,000,000 gal. The quantity of casing-head natural gas treated in the year 1914 by compression and condensation methods amounted to about 17,000,000,000 cu. ft. The average yield of gasoline was 2.43 gal. per 1000 cu. ft. This casing-head natural gas represents gas that formerly went largely to waste, hence the process represented a distinct and important step in the conservation of the natural resources of this country.

A description of the methods employed in the manufacture of casing-head gasoline and a discussion of the tests to determine whether sufficient gasoline is present in a given type of natural gas to warrant the installation of an extracting plant is contained in Bulletin 88 of the Bureau of Mines.

By the compression and condensation method of treating natural gas, only casing-head natural gases, or so-called "wet" gases could be treated, and in order to make the operation profitable natural gases that contain less than $\frac{3}{4}$ gal. of gasoline per 1000 cu. ft. are usually not utilized. Hence there has been exempted not only a large amount of casing-head natural gas, probably more than one-half the available supply, but also the enormous and much larger amount of so-called "dry" natural gas that is used in cities and other places for domestic, factory, and other uses. The quantity of this kind of natural gas consumed in 1914 amounted to 591,000,000,000 cu. ft.*

By absorption methods much of the so-called "dry" natural gas can be treated. The method consists essentially in bringing the natural gas in contact with some kind of a heavier oil than gasoline, or in using a low-grade naphtha, and letting the absorbents absorb the gasoline from the natural gas, and either separating the extracted gasoline from the oil by distillation, or if a naphtha is used, say about 50 deg. Baumé specific

gravity, simply letting this naphtha absorb as much of the natural gas gasoline as it will, thereby increasing the volume and also producing a blend that is intermediate in specific gravity between natural gas gasoline and the naphtha used as an absorbent.

PRODUCTION OF NATURAL GAS IN 1913 AND 1914

Table I gives the production and value of natural gas¹ for the years 1913 and 1914. This table shows a production of 591,866,733,000 cu. ft. of natural gas for the year 1914, an increase of about 10,000,000,000 over 1913.

TABLE I—QUANTITY AND VALUE OF NATURAL GAS PRODUCED IN THE UNITED STATES IN 1913 AND 1914, BY STATES

State	1913			1914		
	Quantity (M Cubic Feet)	Cents per M Cubic Foot	Value	Quantity (M Cubic Feet)	Cents per M Cubic Foot	Value
West Virginia	245,453,985	13.92	\$34,164,850	238,740,162	14.87	\$35,515,329
Pennsylvania	118,860,269	18.25	21,605,845	108,494,387	18.80	20,401,295
Ohio	50,612,211	20.79	10,521,930	68,270,174	21.48	14,667,790
Oklahoma	75,017,668	9.91	7,436,389	78,167,414	10.30	8,050,039
Kansas	22,884,547	14.37	3,288,394	22,627,507	14.76	3,340,025
New York	8,515,257	28.50	2,425,633	8,935,187	29.10	2,600,352
Louisiana	26,652,626	7.95	2,119,948	26,774,695	8.32	2,227,999
Alabama						
Texas	12,159,755	17.05	2,073,823	13,433,634	18.38	2,469,770
California	11,034,597	17.07	1,883,450	17,828,928	16.33	2,910,784
Indiana	2,920,314	28.52	843,047	2,579,675	29.28	755,407
Illinois	4,767,128	12.04	574,015	3,547,841	12.32	437,275
Kentucky	1,821,526	27.99	509,846	1,421,818	34.52	490,875
Arkansas						
Colorado						
Wyoming	1,106,374	24.35	269,421	962,998	22.23	214,103
South Dakota						
North Dakota	66,492	48.87	31,166	60,781	44.78	27,220
Missouri	20,865	32.57	6,795	18,085	29.41	5,319
Michigan	1,805	77.84	1,405	2,042	70.61	1,442
Tennessee	2,400	25.00	600	1,200	25.00	300
Iowa	120	100.00	120	200	100.00	200

All of this gas will not be available for the absorption of gasoline from it, but the largest portion of it will be available. Almost all of the natural gas in the United States contains higher members of the paraffin series of hydrocarbons than methane. The ordinary combustion analysis of natural gas only shows the two predominating paraffin hydrocarbons, usually methane and ethane.¹ The authors have never tested a natural gas that showed methane and ethane that did not contain in addition the higher members of the paraffin series of hydrocarbons when an additional test was made for these constituents. The latter comprise propane, butanes, pentanes, hexanes, etc. The latter two comprise most of the gasoline that is obtained by the absorption method.

These so-called "ethane" gases predominate among the natural gases of the country, undoubtedly to the extent of more than 500,000,000,000 cu. ft. used per year. For instance, all the natural gas used in Pittsburgh, Buffalo, Columbus, Cincinnati, Cleveland, Louisville and hundreds of other towns contains ethane.² The same is true of natural gas produced in Oklahoma, Kansas, California, Texas and other States.

Some natural gases that contain methane as the only paraffin hydrocarbon are found in Louisiana, in the Caddo Fields, at a few places in Oklahoma, in the Murrysville sand, Pennsylvania and at a few other places. These methane gases are the only ones that do not carry gasoline vapors. It may happen in a new well, where the pressure is very high, that not enough of the gasoline is carried by the natural gas to warrant the in-

*A paper read before the Natural Gas Association of America, Pittsburgh, Pa., May 15, 1916. Published with permission of Director of Bureau of Mines.

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⁴Mineral resources of the United States, U. S. Geological Survey, part 2, page 800, 1914, J. D. Northrop.

⁵Burrell, G. A.; Seibert, F. M., and Oberfell, G. G. The Condensation of Gasoline from Natural Gas, Bulletin 88, Bureau of Mines.

⁶Loc. cit., page 753.

¹Northrup, John D. The Production of Natural Gas in 1914. Mineral resources of the United States, 1914, part 2, page 751, U. S. Geological Survey.

²Burrell, G. A., and Seibert, F. M., The Sampling and Examination of Mine and Natural Gases. Bulletin 42, Bureau of Mines.

³Burrell, G. A., and Oberfell, G. G. The Composition of the Natural Gas Used in 25 Cities in the United States. Technical Paper 119, Bureau of Mines.

stallation of a plant to extract gasoline by the absorption process, but the most of the natural gas produced in this country undoubtedly can be treated at the present time.

If one assumes that one pint of gasoline can be obtained per 1000 cu. ft. of gas, there will be extracted 500,000,000 pints of gasoline from 500,000,000,000 cu. ft. of gas or about 60,000,000 gal. of gasoline per year. If one assumes two pints per 1000 cu. ft. then the total becomes 120,000,000 gal. per year. Probably 75,000,000 gal. would be a conservative estimate that can be obtained by treating the natural gas in this country at the present time. In the case of some of the so-called "dry" natural gas that the author tested, three pints of gasoline per 1000 cu. ft. were obtained. If one assumes that gasoline has a value of \$0.20 per gallon, then the total value of the gasoline becomes \$15,000,000 per year. At \$0.25 per gallon the sum becomes about \$19,000,000 per year.

This amount is about 20 per cent of the total value of the natural gas used in 1914 and probably about 7½ per cent of the total quantity of gasoline consumed in 1914.

CONSUMPTION OF GASOLINE

During the year 1909 the quantity of gasoline consumed amounted to about 11,000,000 barrels. In 1914 the amount consumed had increased to 18,000,000 barrels, and it is estimated that the consumption in 1916 will be about 38,000,000 barrels of 42 gal. each or about 1,600,000,000 gal.

CONDENSATION OF GASOLINE IN PIPE LINE

Gasoline condensing in trunk lines is a constant source of annoyance and expense, because of its action on the rubber rings used in the patent pipe couplings, which are now universally used on all large pipe lines in place of the old-style socket and thread "collars."

It softens and decomposes the rubbers until they weaken and give way causing a "blow out," that is, the pipe line will part, causing the gas to escape into the air.

Repairing "blow outs" at all hours of the night is a large item of expense, besides the amount of gas lost in that manner is very great. The expense and annoyance frequently attached to the breaking of a gas line and escape of gas is shown by the recent experience of one of the large natural gas companies.

A report was received at the main office that the pressure on a certain line was falling at the rate of 30 lb. per square inch per hour, although the compression station reported everything normal there. This condition indicated a break in the line and men were immediately dispatched to patrol the line, and locate the difficulty, which was found about midnight. Twenty-six men were used the balance of the night and the next day in order to repair the line.

During this time the pressure had to be raised 70 lb. at the compressing station, and the factory service on the line discontinued.

One company informed the authors that the cost of rubber for couplings used in the pipe lines that transported 100,000,000,000 cu. ft. in 10 years through an 18-in. pipe line for a distance of 35 miles was not less than \$16,000.

This was for the rubber alone and did not include the cost of placing the couplings or other expense.

Thus it would seem that a method for removing gasoline from natural gas, thereby preventing the solvent effect of the gasoline on rubber pipe-line couplings becomes valuable for the latter reason, in addition to the fact that a valuable fuel is recovered for sale.

The Development of the General Process of Passing Natural Gases Through Oils or Naphtha for the Extraction of Gasoline

As in the case of the casing-head gasoline process, the absorption process of extracting gasoline from natural gas has assumed industrial importance as the demand for gasoline increased. The idea follows closely the process of extracting benzole, toluol, and other vapors from gases made by destructively distilling coal. In this process the gases are caused to flow at about atmospheric pressure counter current to a stream of wash oil, a petroleum distillate as so-called "straw" oil or "mineral seal" oil or a coal tar distillate such as creosote oil. Absorbing towers in which this is accomplished are 50 to 75 ft. high and about 10 to 15 ft. in diameter. After the benzole and toluol have been scrubbed from the gas, the charged oil is sent to steam stills where the benzole and toluol are extracted. The process is continuous in that the absorbent oil is used over and over again.

The process has been used for many years in Germany and to a very large extent during 1915 and 1916 in the United States. Many types of absorbers and steam stills and different conditions of temperature and pressure were employed before a standard procedure was evolved. The difference between the process of extracting gasoline from natural gas and extracting benzole and toluol from coke-oven gases is that with the natural gas the absorption is conducted at high pressure. This is an economic necessity because the natural gas at present being treated by the absorption process exists at this high pressure, and cannot be profitably treated any other way. The transportation system must not be disturbed.

There might also be mentioned a process in vogue for a number of years past, and practised at some refineries of subjecting uncondensed gas and petroleum vapors from stills to absorption in naphtha, thereby increasing the gasoline yield considerably.

English patent No. 30,229, issued to Albrecht Von Groeling of Vienna, Austria, Dec. 24, 1909, covers a process for "improvements in or relating to the utilization of natural gases or petroleum distillation gases." The claims follow:

(1) A process for the utilization of natural gases or of petroleum distillation gases, consisting in treating the gases at an adjustable increase pressure and adjustably reduced temperature, by quantities determined beforehand, of an absorption medium, for instance of heavy benzine, the unabsorbed gases being then condensed by the use of high pressure and low temperature.

(2) An apparatus for use in carrying out the process set forth in Claim 1, in which the gas is treated, in a series of absorption apparatus arranged one behind another, at an adjustably varying increased pressure and adjustably varying reduced temperature, with the absorption medium, so that said absorption medium can circulate through the various absorbers, and the heat absorbed during the expansion of the compressed gases is withdrawn directly from the absorption medium for the purpose of cooling the latter.

(3) A process of the kind set forth in Claim 1, in which the gases utilized are first washed at an ordinary temperature and normal pressure with "heavy benzine."

(4) A process of the kind set forth in Claim 1, in which the natural gases escaping from a bore-hole, or petroleum distillation gases are first heavily compressed, then cooled and finally washed, in the state of exceedingly fine division, with cooled liquid benzine or the like, for the purpose of separating portions of the

gas that can be condensed, both the cooling of the benzine required for the washing, and the cooling of the gas utilized after the compression, being effected with the expanding gases escaping from the absorption column, the gas being finally condensed by the use of high pressure and low temperature.

(5) An apparatus for use in carrying out the process set forth in Claim 1 or 4, comprising a column several meters high, filled with benzine or the like, into the bottom portion of which the compressed cooled natural gases enter in a state of exceedingly fine division, the upper portion of the column being provided with an expansion valve through which the washed expanded gases pass downwards through an expansion coil or the like, through the washing liquid, for the purpose of cooling the same, and then proceed to the cooling.

(6) A process of the kind set forth in Claim 1 for utilizing natural gases or petroleum distillation gases by fractional condensation or absorption, in which the absorption medium is obtained by the preliminary condensation of the gas to be utilized, which is submitted to the gases still non-condensed, the cooling required for the condensation or absorption being obtained by the expansion of compressed gases or by evaporation of already condensed products under a relieved pressure, the gas being finally condensed by the use of high pressure and low temperature.

U. S. Patent No. 989,927, applied for in 1906 and issued April 18, 1911, to Geo. M. Saybolt specifies: Claim (1) that natural gas of the kind supplied to cities be subjected at pressures not less than 30 lb. per square inch to a naphtha absorbing menstruum and by the aid of the same under high pressure, effecting the separation in industrial quantity from said gas of a natural gas naphtha, liquid at atmospheric pressure and temperature, and applicable to the uses of petroleum naphtha of similar volatility substantially as described.

Claim (2) The process of obtaining naphtha from combustible gas of natural origin and underground source of the kind supplied by means of wells and pipe lines to the cities for consumption therein, which process consists in subjecting such gas in the requisite large amount on the way from its underground sources to its places of consumption and under a high pressure, not less than 30 lb. per square inch above atmospheric pressure, to a naphtha absorbing menstruum especially petroleum or hydrocarbon oil as specified, and by the aid of the same under said high pressure effecting the separation in industrial quantity from said gas, of a natural gas naphtha liquid at atmospheric pressure and temperature and applicable to the uses of petroleum naphtha of similar volatility, and then recovering the naphtha in liquid form from said menstruum by distillation under a low pressure, not more than about atmospheric pressure, substantially as described.

U. S. Patent No. 1,165,458, issued to John Snee, Dec. 28, 1915, specifies a means of providing for the retention of lighter or more volatile oils contained in the product of oil wells, gas wells and gas wells that produce both oil and gas. The claims follow:

1. The method herein described consisting in discharging all of the liquid and gaseous hydrocarbon products of an oil well into a liquid and gas container, and absorbing the gaseous hydrocarbons which accumulate within the container above the surface of the liquid.

2. The method herein described consisting in discharging all of the liquid and gaseous hydrocarbon products of an oil well into a liquid and gas container beneath the fluid level of the latter, and removing and absorbing the gaseous hydrocarbons released from the liquid within the container.

3. The method herein described consisting in dis-

charging all of the oil from an oil well into an oil and gas container, passing the gaseous products of the well into the oil thus discharged beneath the surface of the latter, and removing and absorbing the gaseous products released from the surface of the oil.

U. S. Patent No. 1,107,803 issued Aug. 18, 1914, to H. Koppers specifies that to extract naphtha from natural gas the latter is passed under pressure through a solvent oil in a cast-iron bell washer which is relieved of pressure by placing it within a wrought-iron casing through which gas passes.

To the authors' knowledge the first large-scale installation for extracting gasoline from natural gas was placed at Hastings, W. Va., by the Hope Natural Gas

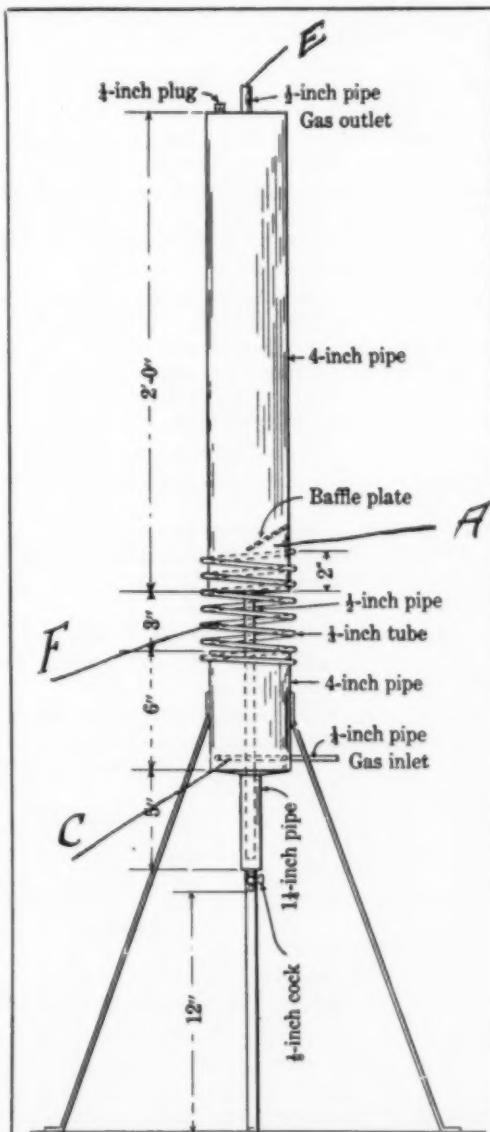


FIG. 1—SMALL ABSORBER FOR TESTING
NATURAL GAS FOR GASOLINE CONTENT

Company of Pittsburgh, Pa. The plant was put in operation in 1913 as a result of the Saybolt experiments. The process consists in causing the natural gas to bubble up through mineral seal oil, the latter being then sent to steam still for the separation of the gasoline and the absorbent oil being used over and over again. The gas is passed through the absorbing oil at the high pressure of the line. The hot oil from the stills is cooled in a double-pipe cooler or exchanger by the cold oil en route to still and further cooled by passing through pipes upon which running water falls.

The general process, except for the utilization of the

gas under high pressure, is identical with the process of absorbing benzol and toluol vapors from coke-oven gases.

TESTING NATURAL GAS FOR GASOLINE CONTENT

In addition to laboratory tests whereby gasoline was frozen out of the natural gas the authors tested natural gas on a small scale with the absorber shown in Fig. 1.

It is built on the principle of a laboratory gas-washing bottle of the Friedrich type.

This absorber was made of iron pipe and thoroughly welded.

It is about 3 ft. high, and the two main barrels, A and B, were made of 4-in. pipe. The gas entering, bubbles up through the absorbing oil at C and passes through the coil of pipe F, and into the part A and out at E.

After the oil contained in the absorber had absorbed all of the gasoline that was desired, a portion of it was withdrawn and subjected to distillation to obtain the gasoline, which was measured and the yield of gasoline per 1000 cu. ft. of natural gas thus determined. This small absorber was designed to show the maximum yield of gasoline possible to obtain.

The process of extracting gasoline from natural gas by passing the latter through oil, simply consists in the solution of the gasoline in the absorbent. In passing natural gas with its gasoline vapor through an absorbent, there will occur a point when a particular oil will not take up any more gasoline. The authors determined that in the case of mineral seal oil this saturation amounted to 28 per cent, as regards tests they conducted.

In conducting the test natural gas was passed through mineral seal oil, using the smaller absorber shown in Fig. 1, until no more gasoline was found to be absorbed by the oil.

By a percentage saturation of 28 is meant that the amount of gasoline absorbed was 28 per cent of the final total volume of gasoline and oil.

But in the practical work of absorbing gasoline from

natural gas, the saturation percentage of the gasoline in the oil cannot be carried that far. It was found from actual tests that when the saturation of the gasoline exceeded 4 per cent, some of the gasoline in the natural gas was passing through the oil unabsorbed, *i.e.*, the extraction was not complete. As a saturation percentage of 4 per cent was exceeded more and more gasoline was absorbed, of course, from the natural gas, but at the same time an increasingly small amount of gasoline appeared in the exit gases.

This small amount was always less than the amount absorbed until a saturation of 28 per cent was reached, when the amount absorbed was equal to the amount given off, *i.e.*, from now on a condition of equilibrium was reached.

Therefore in all tests made both on the small absorbers and on the larger experimental plants a close tab was kept on the saturation percentage of the gasoline in the absorbent.

Two different oils were used as the absorbing medium in extracting gasoline from the natural gas in conjunction with those tests in which steam distillation was used to finally separate the gasoline from the absorbent. These oils were petroleum distillates.

Their characteristics as determined by E. W. Dean, petroleum chemist of the Bureau of Mines, are given in Table II.

TABLE II—MINERAL SEAL

Flash point (Pensky-Martin closed apparatus).....	135° C., 275° F.
Burning point (Pensky-Martin open apparatus).....	160° C., 311° F.
Specific gravity (water = 1).....	0.850

Upon distillation the first drop appeared at 225 deg. C. (405 deg. Fahr.) and 6.2 per cent distilled up to 275 deg. C. (527 deg. Fahr.).

STRAW OIL	
Flash point	182° C., 361° F.
Burning point	208° C., 416° F.
Specific gravity (water = 1).....	0.851

First drop distilled at 250 deg. C. (482 deg. Fahr.) and began to distill in quantity at 275 deg. C. (527 deg. Fahr.).

¹⁰This would occur up to 28 per cent saturation.

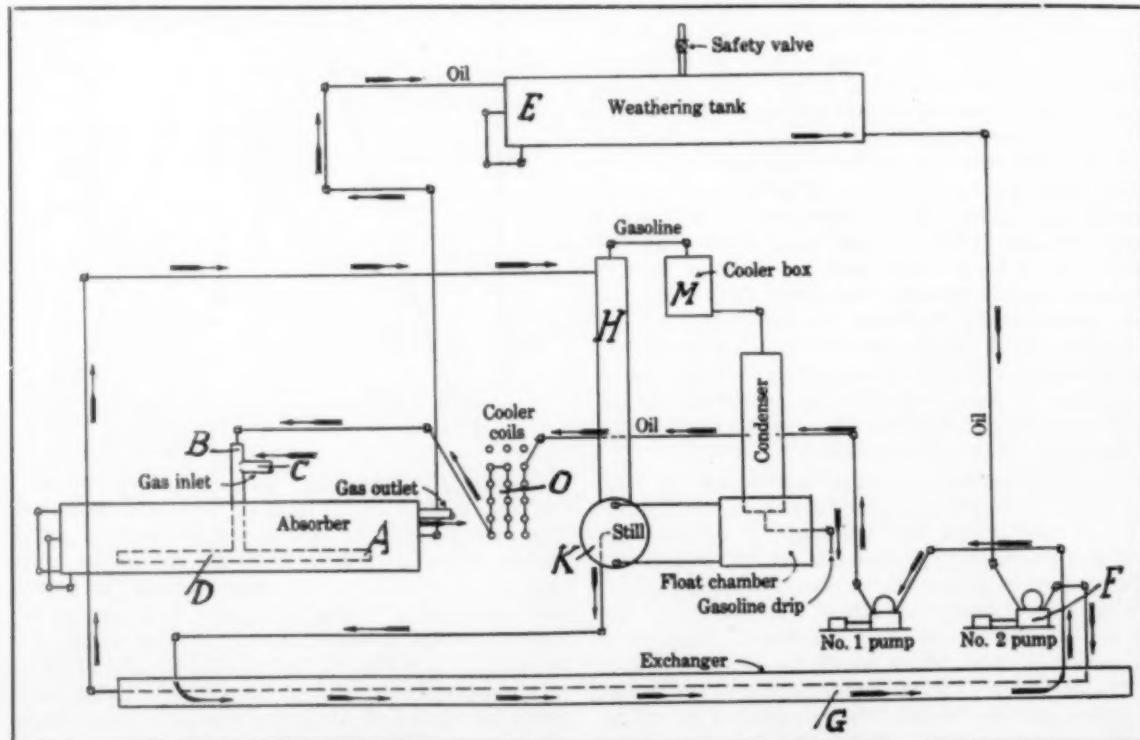


FIG. 2—PLANT FOR ABSORBING GASOLINE FROM NATURAL GAS

Description of Experimental Plants Using Mineral Seal Oil and Steam Distillation

While the tests were under way, using the small-scale experimental plant shown in Fig. 1, tests on a much larger scale were made with the plant shown in Fig. 2. This plant was capable of continuous operation in that natural gas was continuously passed through the absorbing oil and the latter after leaving the absorbers, charged with gasoline, was pumped to the steam still where the gasoline was removed and the oil pumped back to the absorbers to receive another charge of gasoline. This plant had a capacity of from 15,000 to 30,000 cu. ft. per hour.

A diagrammatic view of the plant is shown in Fig. 2.

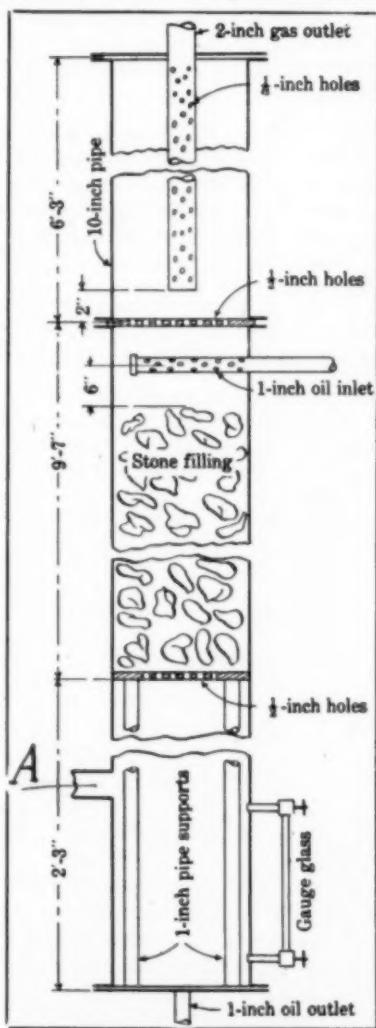


FIG. 3—TOWER ABSORBER

The gas enters the absorbing tank at *C* and the oil enters at *B*. Together they pass into the T pipe *D* and pass from there through many small holes into the oil contained in the absorber. The gas bubbling up through is stripped of its gasoline by absorption in the oil and passes out of the absorber as shown and goes on its way to the cities and other places for consumption.

The oil charged with gasoline passes first to the weathering tank *E*, where the lighter portions of the gasoline are released through the safety valve. Next the oil enters the pump *F* and is pumped through the heat exchanger *G* and from there into the rock tower *H* of the steam still *K*. Live steam enters this still and distills the gasoline from the oil. The cooler *M* is provided to separate the water (condensed steam) from the gasoline. The gasoline is condensed in the condenser and flows out of the system at the gasoline drip.

The hot oil after having been freed of its gasoline is passed through the heat exchanger *G* (thereby heating the oil passing to the still) and from No. 1 pump is forced through the water coils *O*, upon which running water drops. The cooled oil then passes into the absorber *A* to receive another charge of gasoline. The operation is continuous, the oil being used over and over again.

In addition to the type of absorber shown in Fig. 2, several other types of absorbers were used. The most efficient was a vertical or tower absorber shown in Fig. 3. Oil enters as shown and drops onto and through a column of stones of about the size of a fist. Gas enters at *A* near the base of the tower and flows counter current to the oil and out of the gas pipe at the top of the column.

YIELD OF GASOLINE USING THE SMALL ABSORBER SHOWN IN FIG. 1 AND THE PLANT SHOWN IN FIG. 2

In Table III are shown data of tests, using the "plant" shown in Fig. 2. In test 1 the tower absorber was used and in test 2 the absorber shown connected with the plant. The tower absorber gives the best results.

In Table IV are shown some results using the small absorber, shown in Fig. 1 and at different pressures. Pressure conditions made a decided difference. The

TABLE III—TESTS OF NATURAL GAS USING DIFFERENT ABSORBERS

Test No.	TOWER ABSORBER, MARCH 3, 1916					NO. 4 ABSORBER, MARCH 3, 1916				
	1				2					
Time	8	9	10	11	8	9	10	11		
Pressure at inlet to absorber, lbs. per sq. in.	222	215	211	211	225	220	216	215		
Pressure on still, lbs. per sq. in.	3	3	2.75	2.75	3	3	2.75	2.75		
Temperature of oil, deg. F. (in absorber)	58	64	66	68	66	66	66	68		
Temperature of oil outlet, still deg. F.	207	210	208	209	212	212	212	210		
Temperature of vapor outlet cooler, deg. F.	142	170	164	176	170	172	184	172		
Temperature of cooling water, deg. F.	52	52	52	52	52	52	52	52		
Temperature of still, deg. F.	218	216	216	216	216	216	216	215		
Temperature of oil outlet absorber, deg. F.	54	58	60	62	60	58	60	68		
Sp. gr. absorbing oil inlet to absorber, deg. B	34.2	33.7	33.5	34.4	34.5	34.5	34.5	34.4		
Sp. gr. absorbing oil outlet from absorber, deg. B	36.4	36.2	36.0	35.8	35.0	35.2	35.0	34.4		
Yield gasoline, c.c.	17,000	16,000	16,310		9200	9600	11,300			
Gravity gasoline, deg. B	85.2	85.5	85.8		80.3	80.3	82.3			
Gravity of refrigerator gasoline, deg. B	91.1	91.8	90.5		90.3	92.0	90.6			
Volume of refrigerator gasoline, c.c.	1860	2200	2030		2335	2130	1810			
Amount of gas passed, cubic feet.	73	800			1.57			1.18		
Yield of gasoline per 1000 cu. ft., total pints										
Flow of gas—24,600 cu. ft. per hour.										
Gallons of oil circulated per 1000 cu. ft. of gas—7.9.										
Gallons of oil circulated per 1000 cu. ft. of gas—8.7.										

yield increased from 0.71 pint to 1.97 pints as the pressure was increased from atmospheric to 110 lb. per square inch. This is to be expected.

In using these small absorbers they were arranged in series of three for each test. The gas first passed through one absorber where most of the gasoline was extracted and then through the other two.

AMOUNT OF OIL USED PER THOUSAND CUBIC FEET OF NATURAL GAS TO OBTAIN THE LARGEST YIELD OF GASOLINE

A large number of tests were made with different absorbers to determine the proper amount of oil to be used per 1000 cu. ft. of natural gas in order to obtain the highest yield of gasoline. It was found that using the absorber shown in Fig. 2 the best results were obtained when about 7 gal. of oil were circulated per 1000 cu. ft. of gas. Using the tower absorber shown in Fig. 3 the amount of oil circulated could be considerably decreased and just as good results obtained by circulating 4 gal.

TABLE IV—EFFECT OF PRESSURE ON YIELD OF GASOLINE

Date	January 26, 1916	January 29, 1916	January 30, 1916	January 30, 1916	January 31, 1916
Time	2.45 to 3.55 p.m.	2.25 to 3.40 p.m.	9.35 to 10.45 a.m.	1.05 to 2.25 p.m.	8.15 to 9.37 a.m.
No. of absorber	3	4	5	3	4
Kind of oil used	Mineral Seal	Mineral Seal	Mineral Seal	Mineral Seal	Mineral Seal
Specific gravity of oil, degrees Beaumé	34.2	35.0	35.0	35.0	34.2
Amount of oil used, cubic centimeters	1,750	1,500	1,500	1,750	1,500
Pressure on absorber, lb. per sq. in.	Atmospheric	20 lb. gage	40 lb. gage	85 lb. gage	75 lb. gage
Gas rate by meter, cu. ft. per hour	79		85	75	
Ratio, c. c. of oil to 1000 cu. ft. of gas	17,500	15,000	15,000	17,500	15,000
Cu. ft. of gas consumed	100	100	100	100	100
Amount of liquid recovered, c. c.	1,770	1,505	1,510	1,845	1,515
Sp. gr. of liquid recovered, degrees Beaumé	35.1	34.5	34.4	35	35.2
Temperature of liquid recovered, degrees Fahr.	68	67	66	68	69
Per cent saturation of liquid recovered	1.2	0.6	0.3	2.3	1.2
Increase in c. c. of liquid recovered	20	5	10	95	15
Increase, per cent, of liquid recovered	1.1	0.3	0.7	5.4	1.0
Amount of sample, cubic centimeters (for distillation)	590	502	503	615	505
Temperature of condenser bath, degrees Fahr.	48	48	46	46	48
Amount of distillate, c. c.	7.0	3.0	1.8	14.0	5.8
Temperature range of distillate, degrees Fahr.	166-260	190-260	160-260	138-260	130-260
Amount of gasoline obtained, c. c.	21.0	9.0	4.5	42.0	17.4
Amount of gasoline obtained, pints per M cu. ft.	0.44	0.19	0.08	0.888	0.368
Sp. gr. of gasoline, degrees Beaumé				0.171	0.939
Total pints of gasoline per M cu. ft. of gas			0.71	1.427	
				1.489	1.89
				Estimated loss 0.17	1.97
				(See previous test)	

of oil per 1000 cu. ft. of gas. Instead of decreasing the amount of oil, the practice of the authors was to keep the oil rate at about 7 gal. and increase the gas rate. The best results were obtained by using the tower absorber and passing about 28,000 cu. ft. of gas per minute and circulating about 7 to 8 gal. of oil.

DISTILLATION TEST OF GASOLINE

The gasoline obtained by absorption in mineral seal oil and steam distillation rather consistently had a specific gravity on the Beaumé scale of about 80 deg. One of many distillation tests that the authors made of it is shown in Table V. These tests were made on gaso-

posed in glass cylinders, 12 in. high, 4 in. in diameter, and of 1000 cubic centimeters capacity. The first column shows the evaporation loss when the gasoline obtained from natural gas by the absorption process was exposed to the air. The second column shows the evaporation loss, using refinery gasoline obtained from the Standard Oil Company.

CHANGE IN COMPOSITION AND QUANTITY OF THE NATURAL GAS BEFORE AND AFTER THE EXTRACTION OF GASOLINE

Tests which the authors made of the natural gas before and after treatment for the absorption of gasoline are given in Table VII. Natural gas from two lines was tested, low field gas and line L gas.

TABLE V—DISTILLATION TEST OF GASOLINE OBTAINED BY ABSORPTION METHOD

Distillation Temperature, Degrees Fahrenheit	Amount of Distillate by Volume, per Cent	Specific Gravity of Distillate, Degrees Beaumé
80-110	10	91.8
110-124	20	89.0
124-136	30	86.7
136-146	40	83.4
146-158	50	80.4
158-172	60	77.4
172-188	70	73.3
188-208	80	70.2
208-244	90	65.0
244-290	93	63.1
Loss	7	

Experimental plant, December 29, 1915.
Specific gravity of mixture = 80° Beaumé.

line obtained from the large scale experimental plant shown in Fig. 2.

TABLE VI—EVAPORATION LOSS OF GASOLINE

Kind of Gasoline	From Absorption Process	Refinery
Specific gravity of gasoline at start, degrees Beaumé	81.1	60.4
Temperature of gasoline, degrees Fahrenheit	56	63
Temperature of room, degrees Fahrenheit	70	70
Volume of gasoline at start, cubic centimeters	1000	1000
Volume of gasoline after 24 hours, cubic centimeters	895	976
Volume of gasoline after 48 hours, cubic centimeters	840	955
Volume of gasoline after 72 hours, cubic centimeters	800	924
Specific gravity of gasoline after 24 hours, degrees Beaumé	79.6
Specific gravity of gasoline after 48 hours, degrees Beaumé	76.5
Specific gravity of gasoline after 72 hours, degrees Beaumé	76.0	58
Temperature of gasoline after 24 hours, degrees Fahrenheit	56
Temperature of gasoline after 48 hours, degrees Fahrenheit
Temperature of gasoline after 72 hours, degrees Fahrenheit	61	60
Evaporation loss of gasoline after 24 hours, per cent	10.5	2.4
Evaporation loss of gasoline after 48 hours, per cent	16.0	4.5
Evaporation loss of gasoline after 72 hours, per cent	20.0	7.6

EVAPORATION LOSS OF GASOLINE OBTAINED BY ABSORPTION PROCESS FROM NATURAL GAS AND A COMPARISON WITH DIFFERENT BLENDS AND WITH REFINERY GASOLINE

In Table VI there is shown the loss by evaporation, using different grades of gasoline. The liquids were ex-

TABLE VII—TESTS OF FRESH GAS—COMBUSTION ANALYSIS

	Low Field Gas, per Cent	Line L Gas, per Cent
CO ₂	Trace	Trace
CH ₄	76.3	83.9
C ₂ H ₆	18.4	11.7
N ₂	5.3	4.4
Total	100.0	100.0
Specific gravity	0.68	0.63
Absorption in Russian white oil*	17.0	15.0
Gross heating value per cubic foot at 0 deg. C. and 760 mm. pressure	1155.0 B.t.u.	1111.0 B.t.u.

*This Russian white oil is used in the same way that claroline is used, and described on page 32, Bull. 88, Bureau of Mines.

The tests of Table VII were made of gas that had not been treated by the absorption process. Table VIII shows tests of the same gas after it had been passed through absorbers containing mineral seal oil, and after gasoline had been extracted from it.

TABLE VIII—TESTS OF TREATED GAS—COMBUSTION ANALYSIS

	Low Field Gas, per Cent	Line L Gas, per Cent
CO ₂	Trace	Trace
CH ₄	79.7	88.3
C ₂ H ₆	14.1	7.9
N ₂	6.2	3.8
Total	100.0	100.0
Specific gravity	0.65	0.61
Absorption in Russian white oil	16.7	14.0
Gross heating value per cubic foot at 0 deg. C. and 760 mm. pressure	1111.0 B.t.u.	1087.0 B.t.u.

COMMENTS ON ANALYSES

Differences between the natural gas before and after gasoline had been extracted are interesting. In the case of the low field gas, the heating value was lowered 44 B.t.u. or 3.8 per cent, due to the extraction of the

gasoline. The specific gravity dropped from 0.68 to 0.65 and the proportions of paraffin hydrocarbons, calculated as methane and ethane, were altered. In the case of Line L gas, the heating value was lowered 24 B.t.u. or 2.2 per cent and the specific gravity dropped from 0.63 to 0.61.

The quantity of natural gas that disappears due to the extraction of the gasoline is small. It can be calculated as follows: The assumption can be made that the gasoline extracted is all pentane. This assumption is close enough for the purpose. One gallon of pentane produces about 32 cu. ft. of vapor or about 16 cu. ft. of the natural gas are removed for each 4 pints of gasoline extracted. Four pints of gasoline probably represent the maximum of vapor extracted for each two pints of gasoline produced.

VAPOR-TENSION TESTS OF GASOLINE OBTAINED BY OIL ABSORPTION AND STEAM DISTILLATION

Many vapor-tension tests were made of the gasoline. Some of these tests are shown in Table IX. It will be seen that the material does not develop excessive pressures with rise of temperature and that it comes well within the specification for gasoline that can be shipped in tank cars.

TABLE IX.—VAPOR PRESSURE TESTS OF GASOLINE PRODUCED BY OIL ABSORPTION AND STEAM DISTILLATION PROCESS

Date	12-15-15	12-16-15	12-22-15	12-23-15
Specific gravity of gasoline, deg. B.	79	78	77.5	81.5
Vapor pressure, at 70 deg. F., lb. per sq. in.	1.25	1.0	0.5	1.25
Vapor pressure at 90 deg. F., lb. per sq. in.	1.50	1.5	1.0	2.0
Vapor pressure at 100 deg. F., lb. per sq. in.	2.75	2.5	2.5	4.75

The rules of the Interstate Commerce Commission¹¹ regarding the shipment of natural gas gasoline follow.

REGULATIONS FOR THE TRANSPORTATION ON RAILROADS OF NATURAL GAS GASOLINE

"Liquefied petroleum gas is a condensate from the 'casing head gas' of petroleum oil wells, whose vapor-tension at 100 deg. Fahr. (38 deg. C.) to 90 deg. Fahr. (32 deg. C.), Nov. 1 to March 1, exceeds 10 lb. per square inch. Liquefied petroleum gas must be shipped in metal drums or barrels which comply with 'shipping container specification 5' or in tank cars especially constructed and approved for this service by the Master Car Builders' Association. When the vapor tension at 100 deg. Fahr (38 deg. C.) exceeds 25 lb. per square inch, cylinders as prescribed for compressed gas must be used."

UNCONDENSED VAPORS FROM THE STILL

In the process of distillation of the gasoline from the mineral seal oil by means of steam, an appreciable quantity of uncondensed vapors escaped into the air, hence some of them were liquefied by passing the vapors through a 1-in. pipe about 8-ft. long, inside another pipe 2 in. in diameter and 8 ft. long. Compressed natural gas which had been used to run one of the oil pumps (in place of steam) was expanded through the larger pipe to cool and condense as much of the vapors as possible. A temperature of 0 deg. to 4 deg. Fahr. was obtained in this manner. Table X shows the vapor pressure and other data regarding these condensed vapors, using the plant shown in Fig. 2.

The yield of gasoline obtained from the steam still during this test was 0.94 pints of 80 deg. Beaumé gaso-

TABLE X—DATA REGARDING UNCONDENSED VAPORS FROM STILL VAPORS FROM CONDENSER, PLANT 2, DECEMBER 28, 1915

130,000 cu. ft. of natural gas used in the test and 450 cu. ft. of vapor passed through refrigerator.	5 lbs. at 70 deg. F.
Yield: 3 1/4 gallons per 130,000 cu. ft. of natural gas used at plant.	8 1/4 lbs. at 90 deg. F.
Vapor tension test.	11 lbs. at 100 deg. F.
Specific gravity of refrigerator gasoline.	94.9 deg. Beaumé
	EVAPORATION TEST
Time, p.m.	1:15
Volume (cu.)	100
Temperature, deg. F.	60
Per cent loss	25
	1:20
	65
	55
	35
	2:00
	84
	90
	45
	2:15
	50

line per 1000 cu. ft. of gas. The yield of gasoline from the refrigerator was 3 1/4 gal. per 130,000 cu. ft. of natural gas, or 0.2 pints per 1000 cu. ft.; hence 0.2 plus 0.94 pints = 1.14 pints total yield.

EFFECT OF PRESSURE AND TEMPERATURE ON THE ABSORPTION OF GASOLINE FROM NATURAL GAS

The authors found that the yield of gasoline was considerably affected by the pressure under which the absorption was effected. This is to be expected. In one test an increase in the pressure of the gas from atmospheric to 110 lb. per square inch increased the yield from 0.7 pint to about 1.97 pints per 1000 cu. ft. of gas.

An increase in the temperature of the oil in the absorber from about 75 deg. Fahr. to 85 deg. Fahr. lowered the yield about 0.3 pints per 1000 cu. ft. of gas.

COST DATA

As a result of the experiments conducted to date, a much larger plant is contemplated, capable of handling about 50,000,000 cu. ft. of natural gas per day. Exact figures regarding the cost of installing such a plant cannot be given at the present time. It is believed, however, that a conservative estimate is \$1.00 to \$1.50 per thousand cu. ft. of gas handled per day for a "plant" capable of handling 60,000,000 to 90,000,000 cu. ft. and up to \$2.00 per 1000 cu. ft. of gas for a plant of 30,000,000 cu. ft. or less. The returns are large. At \$1.00 per 1000 cu. ft., a plant to handle 60,000,000 cu. ft. would cost \$60,000. If only one pint of gasoline was extracted from each 1000 cu. ft. of gas per day, there would be extracted from 60,000,000 cu. ft. 7500 gal. of gasoline. At \$0.20 per gallon for gasoline, this is \$1,500 per day.

Combination Process of Absorption of Gasoline from Natural Gas by Means of Naphtha and Mineral Seal Oil

This process, heretofore described, of extracting gasoline from natural gas by absorption, consisted in first passing the natural gas through mineral seal oil and then separating the absorbed gasoline from the oil by steam distillation. This process resulted in obtaining from one gas line about 1.2 pints of gasoline per 1000 cu. ft. of gas, and from another line about 1.8 to 1.9 pints of gasoline. This has reference to tests made with the small absorber shown in Fig. 2.

In using the mineral seal oil as the absorbent, it was found that the increase in volume of the mineral seal oil after passing natural gas through it, did not correspond with the quantity of gasoline subsequently obtained from the oil by distillation. This was due to the fact that a considerable quantity of the lighter hydrocarbons was absorbed from the natural gas, increasing the volume of the mineral seal oil, but escaping as a gas when the oil was subjected to distillation to obtain the absorbed gasoline.

The loss of material appeared to be considerable, so a solution was sought that would result in obtaining this material wasted by the oil absorption and distillation process. Therefore several tests were made, using the

¹¹From "Regulations of the Interstate Commerce Commission for the Transportation of Explosives and Other Dangerous Articles by Freight and Express, and Specifications for Shipping Containers," published by the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, in January, 1912; effective March 31, 1912.

TABLE XI—EXTRACTION OF GASOLINE FROM NATURAL GAS BY PASSING THE LATTER THROUGH NAPHTHA LINE L GAS

Test No.	1	2	3	4	5	6
Oil or naphtha used.	Naph- tha	Naph- tha	Naph- tha	Naph- tha	Naph- tha	Naph- tha
Sp. gr. of oil or naphtha, deg. B.	53.5	53.5	32.5	55.5	55.5	55.5
Pressure on gas, lb. per sq. in.	235	235	235	235	235	235
Gas rate, cu. ft. per hour	50	50	50	55	55	55
Amount of gas used, cu. ft.	200	200	200	105	105	105
Oil used, c. c.	1750	1500	1500	1750	1500	1500
Oil recovered, c. c.	1050	1640	1565	1925	1560	1510
Sp. gr. of liquid recovered, deg. B.	61.6	60	37.7	39.6	38.0	36.3
Temperature of liquid in absorber, deg. F.	27	29	26	19	19	19
Increase in liquid in absorber, c. c.	200	140	65	175	60	10
Percentage increase in liquid in absorber				100	55	100
Sample of mineral seal oil for distillation		500		500		533
Amount of gasoline distilled from mineral seal oil, c. c.		7		2		25
Yield of gasoline, pints per 1000 cu. ft. of gas	2.114	1.480	0.687	3.53	1.21	0.12
Total yield, pints per 1000 cu. ft. of gas		4.28		4.86		2.70
						4.10
						3.07
						4.06

small absorbers of the type shown in Fig. 2 with naphtha, specific gravity 55 deg. Beaumé in the first two absorbers and mineral seal oil in the third absorber. The object was to absorb as much of the gasoline as possible, including the lighter hydrocarbons, in the first two absorbers and the rest of the gasoline in the mineral seal oil. Table No. XI shows the results of these tests.

COMMENTS ON TESTS

It will be observed that the gasoline extracted from the natural gas by passing the latter through naphtha amounted to 4.86 pints per 1000 cu. ft. of gas in the case of one test. The lowest yield was 2.70 pints. The increase in yield over the oil absorption and distillation method varied between 300 and 500 per cent.

In test 1 the specific gravity of the naphtha was raised from 53.5 deg. Beaumé to 61.6 deg. Beaumé in the first absorber and to 60 deg. Beaumé in the second absorber. The increase in volume of the naphtha in first absorbers was 200 c.c. or 11.5 per cent, and in the second absorber 140 c.c. or about 9.3 per cent.

The greatest increase in volume and specific gravity of the naphtha was obtained in No. 1 absorber, test 4. The specific gravity of the naphtha was raised from 55.5 deg. Beaumé to 62 deg. Beaumé and the increase in volume was 290 c.c. or about 16.6 per cent.

The vapor pressure of the resulting naphtha in No. 1 absorber, test 4, was 5 lb. per square inch at 100 deg. Fahr., and the evaporation or weathering loss was 5 per cent in 24 hours. During this weathering test the temperature of the gasoline increased from 54 deg. Fahr. at the start to 64 deg. Fahr. at the finish. The temperature of the room changed from 56 deg. Fahr. to 64 deg. Fahr.

The temperature of the naphtha had much influence on the results of the tests. The highest yield was that shown in test 2 where the temperature of the naphtha was 19 deg. Fahr. This test was conducted in the open air on a cold winter day. However, even at a temperature of 60 deg. Fahr. a yield as high as 3.07 pints of gasoline per 1000 cu. ft. of gas was obtained. Test No. 6 was instructive in that the vapor pressure of the resulting naphtha in No. 1 and No. 2 absorbers was 14 lb. per square inch at 100 deg. Fahr. In other words, its vapor pressure exceeded that prescribed for gasoline to be shipped in tank cars.

In summing up the use of naphtha as an absorbent for extracting gasoline from natural gas, it can be stated that a greater yield can be obtained than by using the oil absorption and distillation process, as much as 300 per cent greater at ordinary temperatures and 400 to 500 per cent greater if temperatures as low as 18 deg. to 19 deg. Fahr. are employed. A further advantage lies in the fact that the resulting naphtha with its absorbed gasoline does not have to be subjected to distillation to obtain gasoline but can be sold as prepared.

An objection to it lies in the fact that a large amount of naphtha would have to be handled in large-scale operations. Mineral seal oil can be used over and over again with but slight loss while the naphtha would have to be constantly received.

The greatest increase in volume of the naphtha was 16.6 per cent in test 4. This amounts to about 6 to 7 times as much naphtha as gasoline, i.e., for each tank of gasoline extracted from the natural gas there would be needed 6 or 7 tanks of naphtha. One cannot absorb too much gasoline in the naphtha else the vapor pressure of the resulting mixture exceeds the limit (10 lb. per square inch at 100 deg. Fahr.) set for the transportation of gasoline in tank cars.

If an absorption gasoline plant could be located at or close to a refinery where a large supply of naphtha was available, the difficulty and trouble of transporting large quantities of naphtha into the absorption plant would be largely overcome, but in most, and perhaps all, cases this is not feasible. A real obstacle at the present time is the difficulty of getting naphtha.

One can look at the problem in the following way:

By the oil absorption process there is obtained one-third as much gasoline as by the naphtha process. One tank car (10,000 gal.) of the absorption process gasoline sells for about 20 cents per gal., or \$2,000. (This figure, however, will vary.) Three tank cars will sell for \$6,000, or an increase of \$4,000. But in order to secure this increase of \$4,000, about seven tank cars of naphtha would have to be brought into the absorption plant, i.e., seven times as much naphtha would have to be handled as of gasoline extracted.

Adaptability of the Absorption Process to Casing-Head Natural Gas

The authors have not made experiments to date regarding the applicability of the absorption process to casing-head natural gas, i.e., natural gas containing a comparatively large proportion of gasoline vapor and at present treated by compression and condensation methods.

The "dry" natural gases used in the experiments described in this report contained from 1 to 2 pints of gasoline per 1000 cu. ft. of gas, and at least 4 gal. of absorbing oil were calculated for 1000 cu. ft. of gas to obtain the highest yield of gasoline. On the same basis, about 32 gal. of oil would have to be circulated for each 1000 cu. ft. of casing-head natural gas that carried 1 gal. of gasoline per 1000 cu. ft. of gas, or about 64 gal. of oil for casing-head natural gas containing 2 gal. of gasoline per 1000 cu. ft. of gas. If 30,000 cu. ft. of gas per hour were treated, then $30 \times 64 = 1920$ gal. of oil would have to be circulated per hour. There are many casing-head compression plants treating 30,000 to

50,000 cu. ft. per hour and obtaining 2 gal. of gasoline per 1000 cu. ft. of gas.

Another possibility is the working of the two processes together on casing-head gas. The gas might be compressed and condensed in the ordinary manner first and the exit gases passed through a small absorbing plant to extract gasoline not completely extracted by the compression method. Waste gases from compression plants contain gasoline that has not been completely extracted. It does not do any good to pass them back through the plant again because they would be subjected to the same process as before, but it might be feasible to pass them through an absorption plant. A point in favor of the absorption process as compared to the compression and condensation method lies in the fact that the gasoline obtained by the former process is not so "wild" as that usually obtained by the latter method.

At present the application of the process to casing-head gases is largely conjecture on the part of the authors, but experiments will be conducted in the future along this line. However, one is safe in saying that there is a great deal of casing-head natural gas at present going to waste that, while considered too lean to work by the compression method, could be treated by the absorption method.

Summary

The absorption method of extracting gasoline from natural gas consists in bringing natural gas in contact with an oil heavier than gasoline, *i.e.*, a petroleum distillate of about 34 deg. Beaumé, letting the absorbent absorb the gasoline from the natural gas, and then separating the gasoline from the oil by distillation. The oil is simply used as a carrier of the gasoline from the absorption tank to the still. It is used over and over again.

This method is different than the extraction of gasoline from casing-head natural gases by compression and condensation methods. By the latter method natural gases that are comparatively rich in gasoline vapor are treated, *i.e.*, those carrying upwards of $\frac{3}{4}$ gal. of gasoline per 1000 cu. ft. of natural gas. So-called "dry" natural gas cannot be treated by this method. By "dry" natural gases are meant those used in cities, towns and factories for heating, lighting and other purposes. The quantity consumed of this kind of natural gas amounted in 1914 to 591,000,000,000 cu. ft. Most of this natural gas carries gasoline to the extent of 1 to 2 pints per 1000 cu. ft. of gas. Probably 75,000,000 gal. of gasoline per year can be obtained by treating much of this natural gas at the present time.

In the case of two natural gases that the authors of this paper experimented with, the heating value was only lowered 3.8 per cent in one case and 2.2 per cent in another case by the extraction of the gasoline.

Besides the obtaining of valuable fuel, gasoline, a further advantage of the process lies in the resultant protection of pipe lines against the deteriorating effect of gasoline on coupling rubbers. The replacing of these rubbers and the repairing of broken connections and loss of natural gas thereof has been a large item of expense in gas transportation companies' operating costs.

The absorption process of extracting gasoline from natural gas assumed industrial importance as the demand for gasoline increased. The scheme is practically identical with the process of extracting benzole and toluol (light oil) from coke-oven gases, a process used for years in Germany and to a very large extent during the years 1915 and 1916 in the United States. A difference lies in the fact that coke-oven gases are treated at about atmospheric pressure while natural gas is treated

at pressure as high as 200 to 300 lb. per square inch. This is an economic necessity because natural gas is transported at high pressures, and it is not desirable to disturb the system.

To the best of the authors' knowledge the first large-scale installation for extracting gasoline from natural gas by the absorption process was placed at Hastings, W. Va., by the Hope Natural Gas Company of Pittsburgh, Pa. Operations commenced in 1913. The plant was built following experiments by George M. Saybolt.

Natural gas can be tested as regards the practicability of extracting gasoline from it by the absorption process by two methods. One is a laboratory method whereby the gasoline is frozen out of the natural gas and its pressure and volume determined. The other method is a field method.

A small absorber and a gas meter can be taken to the well or pipe line to be tested for natural gas, the gas passed through the absorbent and the extracted gasoline distilled from the oil. In other words, a duplicate on a small scale of the commercial method.

All natural gases, except those that contain methane only as the combustible gas, contain gasoline vapor. However, in some cases the amount contained may be very small. This is sometimes due to the fact that gas wells are under very high pressures, and this high pressure keeps the gasoline back in the well. But even those high-pressure wells represent potential sources of gasoline supply in that natural gas will carry commercial quantities of gasoline vapor as the pressure declines.

Natural gas from two different fields that the authors tested contained gasoline to the extent of 1 pint per 1000 cu. ft. in one case and 1.5 pints in another case. About 50,000,000 cu. ft. of natural gas per day was available for treatment.

Oils which the authors experimented with to act as absorbents for the gasoline were about 35 deg. Beaumé specific gravity and started to boil at about 400 deg. to 462 deg. Fahr. They were petroleum distillates. It is necessary that their boiling point be much higher than the boiling point of the gasoline to make the extraction of the latter by distillation easy.

Tests were made on a plant of fairly large proportions, capable of handling 15,000 to 30,000 cu. ft. of gas per hour. The plant consisted of an absorber where the natural gas and absorbent oil were brought in contact with each other, a heat exchanger where the oil with its absorbed gasoline was heated before going to the still, a steam still where the gasoline was extracted from the oil, a cooler where the hot oil from the still was cooled before receiving another charge of gasoline, pumps, weathering tank, etc.

Several different types of absorbers were tried. The one giving the best results consisted of a stone tower down which the oil flowed and up which the gas passed.

An increase in the temperature of the oil in the absorber from about 75 deg. Fahr to about 85 deg. Fahr. lowered the gasoline yield about 0.3 pint per 1000 cu. ft. of gas. An increase in the pressure of the gas from atmospheric pressure to 110 lb. per square inch increased the yield from 0.7 pint to about 1.9 pints of gasoline per 1000 cu. ft. of gas.

The specific gravity of the gasoline obtained varied between 77 deg. Beaumé and 85 deg. Beaumé. The boiling points ranged from 80 deg. Fahr to 300 deg. Fahr. The evaporation loss was about 11 per cent in 24 hours as compared to straight refinery gasoline 60.4 deg. Beaumé, having an evaporation loss of about 2.4 per cent in 24 hours. The vapor pressure of the gasoline ranged from 1 lb. at 70 deg. Fahr. to about 5 lb. at 100 deg. Fahr. This is important because it shows that the gasoline can be shipped in tank cars.

Some tests were made in which the natural gas was simply passed into a naphtha of about 55 deg. Beaumé. When the naphtha had absorbed all the gasoline that was desired it was removed and fresh naphtha substituted. By this scheme there were obtained yields of gasoline varying between 300 and 500 per cent greater than that by the oil absorption and distillation process. In some cases the naphtha, besides being increased in volume due to the absorbed gasoline, was raised in specific gravity to 60 deg. or 62 deg. Beaumé. An objection to the process lies in the fact that a large amount of naphtha has to be handled—at least seven tanks of naphtha for each tank of gasoline obtained.

There are possibilities in the application of the absorption method of treating natural gas to the casing-head natural gas, much of which is treated at the present time by compression and condensation methods.

The authors of this report are indebted to C. F. Ward and A. M. Ballard, engineers of the Ohio Fuel Supply Company, who rendered valuable aid during the entire experiments, and to Dr. G. A. Hulett, consulting chemist of the Bureau of Mines, for assistance in conducting the naphtha absorption experiments.

Cost-Accounting in the Construction and Operation of a Copper Smelter

BY ERNEST EDGAR THUM, E.M.*

Operating Accounts

After the completion of a unit of the plant, operations will commence immediately. In fact, the urgency to blow in may be so pressing that operations will be started long before the finishing touches have been given to the department. It is evident, therefore, that a clear distinction should be made between operating and construction accounts. This may easily be done by prefixing "O" (operating) before the main account number, and using letters for sub-numbers; thus retaining a close correlation between construction and operating accounts in conjunction with a sharp differentiation.

A list of operating accounts for our smelter will now be given.

STORAGE-BINS OPERATING EXPENSES: ACCOUNTS O 10 TO O 19	
Ore-Bedding Plant	.0 10
Thawing Shed	.0 11
Sampling-Mill Bins	.0 12
Blast-Furnace Bins	.0 13
Roaster Bins	.0 14
Reverberatory Bins	.0 15
Converter Bins	.0 16
Flue-Dust Bins	.0 17
Boiler-House Bins	.0 18
SAMPLE-MILL OPERATING EXPENSES: ACCOUNTS O 20 TO O 29	
General	.0 20
Crushing, Elevating, Screening and Cutting	.0 21
Conveying	.0 26
Power Transmission	.0 27
Bucking, making up samples	.0 28
BLAST-FURNACE PLANT OPERATING ACCOUNTS: ACCOUNTS O 30 TO O 39	
General	.0 30
Smelting	.0 31
Water Supply	.0 34
Elevating	.0 35
Sluicing	.0 36
ROASTING-PLANT OPERATING ACCOUNTS: ACCOUNTS O 40 TO O 49	
General	.0 40
Smelting	.0 41
Jacket Water	.0 44
Elevating	.0 45
Conveying	.0 46
Power transmission	.0 47
REVERBERATORY-PLANT OPERATING ACCOUNTS: ACCOUNTS O 50 TO O 59	
General	.0 50
Smelting	.0 51
Waste-Heat Boilers	.0 54
Fuel Plant	.0 55
Sluicing	.0 56
Lining Ladles	.0 59

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CONVERTER-PANT OPERATING ACCOUNTS: ACCOUNTS O 60 TO O 69

General	.0 60
Smelting	.0 61
Crane Work	.0 64
Casting Slag	.0 65
Refining Copper	.0 66
Casting Copper	.0 67
Loading Copper	.0 68
Lining Ladles	.0 69

MAIN FLUE AND STACK OPERATING ACCOUNTS: ACCOUNTS O 70 TO O 79

General	.0 70
Refining Fume	.0 71

BOILER-HOUSE OPERATING EXPENSES: ACCOUNTS O 80 TO O 89

General	.0 80
Fuel	.0 81
Washing	.0 82
Stoking	.0 85
Handling Ashes	.0 86
Condensing	.0 87
Feed Water	.0 88

POWER-HOUSE OPERATING EXPENSES: ACCOUNTS O 90 TO O 99

General	.0 90
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TRAMMING AND WEIGHING OPERATING EXPENSES: ACCOUNTS O 110 TO O 119

Interconnecting	.0 110
Slag Tracks	.0 112
Blast-Furnace Charging Tracks	.0 113
Roaster Charging Tracks	.0 114
Reverberatory Charging Tracks	.0 115
Converter Charging Tracks	.0 116
Flue-Dust Tracks	.0 117
Copper Tracks	.0 118

SHOPS' OPERATING EXPENSES: ACCOUNTS O 120 TO O 129

Machine Shop	.0 120
Smelter Mechanics Shop	.0 121
Boiler Shop	.0 122
Blacksmith Shop	.0 123
Carpenter Shop	.0 124
Pipe Shop	.0 125
Electricians Shop	.0 126
Bricklayers and Masons Shop	.0 127
Locomotive and Car-Repair Shop	.0 128
Crane-Repair Shop	.0 129

MISCELLANEOUS OPERATING EXPENSES: ACCOUNTS O 130 TO O 150

General Office	.0 130
Laboratory	.0 131
Change House	.0 132
Warehouse	.0 133
Outside Toilets	.0 137
Watchmen	.0 138
General Yard	.0 140
Yard Lighting	.0 141
Fire Department Expense	.0 144
Water Development	.0 145
Telephone System	.0 146
Weather Bureau	.0 147

The operating accounts are susceptible of uniform subdivision in an analogous manner to the construction accounts. The general accounts of the O 20 class may be subdivided as follows:

- A Lighting and Heating: Including
Wages of caretakers.
Globes, carbons, cocks and supplies of short life.
Electric current.
Steam.
- B Superintendents and Clerks: Salaries and Supplies.
- C Allowance for Depreciation.
- D Allowance for Repairs and Renewals.
- E Unclassified: Including
Labor and supplies not chargeable elsewhere.
Per cent of miscellaneous operating expenses.
Per cent of unlisted overhead expense.

To this list should be added, in the case of Account O 90, "power house," another subdivision covering the wages of tenders, and oilers, together with such supplies as oil, grease, waste, packing, belt-dressing, and charts. The account for power-house operating has not been subdivided into various classes of equipment owing to the fact that it is usually impossible to properly distribute such items to the different engines unless the installation is an unusually large one, or different classes are housed in different buildings. This account, together with others as noted, is an "expense" and will be distributed in this particular case into the operating accounts proportionately to their power consumption. A method of handling such expenses in such a manner that the rates charged for power may be constant for a fiscal year, has already been discussed at some length, and need not be further dwelt upon in this place.

The very important accounts classed as "smelting"

(O 41 class) should be minutely subdivided in the following manner:

- A Proportion of storage-bin expense chargeable to department material.
- B Proportion of trammimg and weighing expenses chargeable to feeding furnaces. Includes cost of trammimg fine dust from any source to this department.
- C Furnacemen.
- D Fluxes.
- E Fuel.
- F Blast (proportion of power-house expense).
- G Firemen.
- H Sampling, plus proportion of sampling-mill operating expense.
- I Assaying (proportion of laboratory operating expense).

The above will indicate how the various "operating expenses" will be absorbed by the producing departments, and the net result of the accountants' labors will be a statement showing all legitimate expenses of every kind incorporated into the total cost of metal production. The receipts for the sale of this metal must evidently be greater than the total cost of production in order that the company remain solvent.

Importance of Operating Accounts

The remarks made hitherto regarding the desirability of maintaining a proper cost system in addition to the bookkeepers' accounts, the method of collecting and recording information about the labor, material and expense incurred, the necessity of accurate estimation of stocks on hand and material in process, apply with even greater emphasis to the keeping of operating costs, accounts and expenses. The costs will show very graphically the condition of affairs in each department. The departmental heads will receive periodic comparative statements of their condition with certain pointed remarks appended, and it will only be a short time before each man in the works will feel the influence of these figures spurring him toward greater efficiency. Further, the costs will afford the manager ample data for a careful study of the plant's operation leading toward the effecting of economies and the installation of improvements. We may with propriety reiterate our argument that scientific exactitude in the minutiae of costs is neither practicable nor desirable as a matter of daily routine, but the system should have such information latent, to be yielded upon demand. The accounting system should be rigidly exact; and in the end should show how much it cost to operate the industrial system. Many accounts will measure up to this mark, but few will reveal the cost of repairs and operation of "electric locomotive No. 5." Yet without such information the manager has little to guide him in the choice of the most economical traction for a new department.

Repair and Renewal Accounts

With the beginning of the wear and tear of operation will come the necessity of making expenditures for repairs and renewals. Every construction account will have its corresponding repair account bearing the same number and merely distinguished by the prefix "R".

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Thus, if Account C — No. 2 covers the steelwork in the

4

flue connections for No. 2 Reverberatory, and it is desired to replace a broken tie-rod, the proper shop order will be made out by the reverberatory foreman, the work

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done, and the entire cost charged to Account R — No. 2;

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In case a bad accident should demolish this connection and thus cause repairs of considerable amount, costing above a fixed figure, say \$100.00, the superintendent will issue a repair order to the foremen who will be expected to do the work, giving directions as to the work

to be done, and instructing them to charge their expense

52

to 1R — No. 2. Subsequent orders for large repair or

4

renewal jobs on the same equipment will be numbered serially 2R, 3R and so on. The significance of this nomenclature is evident: the first (1) repair order (R) for the steelwork (—) on reverberatory furnace (52)

4

number two (No. 2). All such repair expense will upon completion and closing of the order, be charged into

52

R —, and absorbed by the operating account O —.

4

D

It is evident that the account books made up for the construction foremen can be immediately put into use by the operating foremen. A construction account is transformed into a repair account of exactly the same significance and scope by simply prefixing "R" instead of "C". The operating accounts will be printed in a uniform manner with the construction or repair accounts, and added to the book, together with terse instructions as to the meaning and scope of each account and subdivision. Much repetition can be avoided by the formulation of general rules distinguishing between operating and repair charges, and by explaining that all accounts of the same class, "general," "furnace" or "shops" are to be uniform in designation and significance.

Improvements and Reconstruction

After our smelter has been in operation for some time there will arise the desirability of replacing units of equipment which have become worn out through age, or obsolete in consequence of improvements in the technology. Economy and policy will demand the installation of new departments to utilize by-products or eliminate nuisances. The proper handling of such accounts will now be considered.

We need not discuss at further length the accounting for extensions. A new department added to an old plant is as truly "new construction" as the construction of the original plant. A new series of accounts will be opened covering each new department, the costs during construction being obtained as before, and the total expense incurred will be borne by an appropriation from the general funds or by sale of stocks and bonds. The cost new will be added to the assets, as a part of the value of the plant. Suitable operating accounts will be opened and repairs, renewals and depreciation cared for in the usual manner.

A different procedure is necessary in the case of reconstruction. Suppose it becomes desirable to remove as obsolescent a steam-power plant before its value has been written off by depreciation, and substitute therefor a gas-producer and gas-engine plant. We will assume that the boiler house, constructed under Accounts C 80 to C 89 will be retained for furnishing steam for heating purposes and for blowing under the producers. The power-house equipment, however, will be nearly all replaced as rapidly as possible by the more modern machinery, utilizing with only minor changes the old building and certain pieces of the old equipment.

We will need to consider briefly the method of handling the following varieties of accounts:

- Extensions to old building.
- Minor alterations and adaptations in the old building.
- Present value of the old building.
- Dismantling and removing machinery and appurtenances.
- Present value of old machinery.
- Cost and erection of new machinery.
- Temporary changes necessary to keep operating.

The building was originally constructed under Account C 90, which was further segregated into some

score of sub-numbers. Since the commencement of operations each part of the building has had ample repair work done upon it to keep it in first class condition, and its actual worth as a building is far in excess of its present book value, which, we will assume, has been reduced to some 60 per cent of the original cost by allowances for depreciation.

The account covering "gas engine building" may be C 150, and will be subdivided exactly as the old account C 90. Each of these sub-accounts will bear the cost of any additions to the existing building or its appurtenances, the funds necessary being obtainable from capital account, and will form a legitimate basis for a corresponding increase in capitalization, the cost of such additions being added to "assets" as "value of plant." Minor alterations to the old building should be charged to the appropriate repair account; for instance, if the tool room has to be moved to make room for new machinery, such

90

expense should be borne by Account R —, inasmuch as

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no value is actually added to the building by such an operation—a mere adaptation to the new conditions. On completion of the reconstruction, the book value of C 90 will be transferred into C 150, item to item, when the total of Account C 150 will represent the present value of the building in its enlarged and remodeled state. Obviously, future repairs to any part of the building, new or old, will be charged to R 150; Account 90 has ceased to exist.

A different state of affairs is encountered with Account C 93, covering "blast furnace blowers." We will assume that a battery of impeller blowers belted to a line-shaft driven by a steam-engine will be replaced by centrifugal blowers, direct-connected to motors. Evidently, little if any of the old installation can be utilized in the new, consequently a dismantling account with appropriate sub-numbers will be opened, called D 93, and the book value of C 93 will be transferred thereto, item to item, each of which will now be considered.

1. Excavation and Backfilling.
2. Foundation.
3. Floors and Paving.

The above will represent practically a dead loss. It will be unfair to charge No. 1 to the new account, as this will be charged with the necessary expense of blasting out the old foundations. The old foundations will actually be a hindrance to the new work, and will have no value to the new sub-number 2 except perhaps to furnish a little rubble. Any special floors and paving for an impeller installation can hardly be utilized as such.

4. Machinery and Erection. None of this will be utilized in the new installation. Cost of removal and

93

storing will be borne by Account D —.

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6. Wiring and Lighting.
7. Steam Piping.
8. Water Piping.

All this will have to be torn out, which expense together with the present value will be borne by appropriate sub-numbers under the dismantling account D 93. This will represent almost a total loss, as little useful material will be reclaimed.

9. Air Piping. This sub-number will cover only the construction of the connections between each blower and the main transmission line, and must be removed. Considerable sheet-steel of value will be recovered, however.

It will be noted that this account represents almost the precise antithesis of the building account—none of it will be useful as such in the reconstruction. The special dismantling account must, therefore, bear the cost

of removal, and it will be credited with the receipts of sales of the reclaimed machinery and miscellaneous material when this is effected. The balance, and it is certain to be a large one on the debit side, must be charged into profit and loss, and eventually absorbed by the operating and producing departments.

Account C 93 has, therefore, ceased to appear in the general statement as an asset. Its place will be taken by C 153 which will represent the complete cost and installation of the new units, exactly as though they were installed in a new building on a new site. Any excess in the first cost of this new installation above the first cost of the old will be a legitimate item upon which to base an increase in capital stock. The balance of the funds for the new construction will be derived from the total depreciation allowed to Account C 93 plus the receipts from the transfer of the old blowers and machinery to the dismantling account D 93—now a "supply" account in that it holds sundry second-hand material pending sale.

These two cases discussed at some length represent the two extremes—every shade of gradation may occur in practice. They can be properly handled by considering the different subdivisions in one manner or the other—either of use, or of no use—and treating each item accordingly. Some items may be quite complicated, such as a job of re-wiring, improving and changing the arcs in a lighting circuit. The various kinds of work are so intermixed that segregation would be impracticable. In such an event, the value of the new equipment minus the first cost of the old would represent added value and is chargeable to assets. In this, as in all foregoing remarks, it is assumed that the ordinary method of corporate accounting is in use; such that the liabilities item "capital stock" retains a constant value. This requires that the sum of the two items "present value of plant" and "total allowances for depreciation" must constantly equal the first cost of installation, which cost was carried originally by an appropriation from the general funds.

In case the reconstruction of a department is undertaken during operation, another class of charges will occur, viz., temporary work which is required in order to keep the rest of the plant in operation. In our hypothetical case, suppose it was necessary to construct a by-pass in the air main around the site of the new installation, together with a temporary connection to the converter blowers with the proper pressure-reducing appliances. This work is made necessary by the new construction, but only because it is desired to keep the plant in operation during this period. Adding this expense to that of the new construction would increase its total cost above normal by these items representing no permanent value. If the conditions of the trade should warrant the continuation of operations during reconstruction, it is only fair that operation should bear the cost of these temporary expedients, constructing them under repair and renewal orders, the cost being eventually absorbed by the operating accounts.

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Dedication of New Technology Buildings.—The new Massachusetts Institute of Technology at Cambridge, Mass., will be dedicated on Wednesday, June 14, during the big reunion which takes place June 12 to 14. The dedication will be held in the great court of the new buildings. Inspection of the new buildings will be on Monday, June 12, when members of the Technology Regiment will act as guides for alumni and their friends who visit the buildings. The public are invited to inspect the new buildings on June 15, 16 and 17 and see the exhibit "Fifty Years of Technology."

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Potash in Banana Stalks.—In the course of an examination of the banana stalk for paper making, it was found that the stalk contained potash. In the *Journal Soc. Chem. Ind.*, April 29, 1916, R. H. Ellis gives the following composition of the stalk.

	Ellis	Hanley
Moisture in original stalk, per cent.....	91.6	92.7
Dried matter in original stalk, per cent.....	8.4	7.3
Ash in original stalk, per cent.....	2.4	1.5
Potash in original stalk, per cent.....	1.14	0.9
Ash in dried matter, per cent.....	29.9	20.5
Potash in dried matter, per cent.....	13.73	12.35
Potash in ash, per cent.....	45.9	59.1

Dr. Hanley also extracted the juice by pressure in a small meat press, and found it to contain 0.7 per cent potash. From the above figures it will be noted that the dried matter is as rich in potash as kainite. Thus, from the figures, 1 ton of banana stalks will yield 188 lb. of dried matter containing 13.7 per cent of potash (K_2O), or 54 lb. of ash containing 47.5 per cent potash, or 25 lb. of pure potash. When stripped they have an average weight of 4 lb. each or 16,000 lb. in all, representing 1340 lb. (about 12 cwt.) of dried matter as rich in potash as kainite.

Substitute for Sodium Sulphide in Leather Industries.—A common method of unhairing hides and skins is by means of sodium sulphide in conjunction with milk of lime. Some experiments on the use of a substitute are described by J. E. PICKLES in the *Journal Soc. Chemical Industry*, April 29, 1916. About 1860 the use of a mixture of sulphur with lime and sodium carbonate was proposed by Lufkin, and used in the United States with some success. A series of experiments was made with these materials. When sodium sulphide is dissolved in water it is hydrolyzed with the formation of sodium sulphhydrone and hydroxide, and it has been proved that the sulphhydrone is the active depilatory agent, the caustic soda serving to swell the hide fibres: 78 parts of sodium sulphide produce 33 parts of sulphhydrone, SH (neglecting the weight of the sodium), and 40 parts of caustic soda. If sulphur is boiled with milk of lime, a certain amount of calcium sulphhydrone is formed, together with some polysulphides, the latter being not detrimental, if not actually advantageous, to the process. As the results of the experiments, it was found that if $\frac{1}{2}$ lb. sulphur is boiled with lime, the same unhairing effect is obtained as with 1 lb. of sodium sulphide or 3 lb. of $Na_2S \cdot 9H_2O$ ordinarily used. To obtain the same amount of caustic soda in the lime, as if the sulphide had been actually used, is of course a simple matter, since if sodium carbonate is added to the lime water calcium carbonate and sodium hydroxide are produced; roughly 11 oz. of anhydrous sodium carbonate or 33 oz. of soda crystals will give the same amount of caustic soda that is obtained from 1 lb. of sodium sulphide or 3 lb. of $Na_2S \cdot 9H_2O$.

The procedure is as follows: the calculated amounts of sulphur and of sodium carbonate are weighed, the sulphur is added to the lime when slaking, and if necessary boiled with the lime until all sulphur is dissolved. This gives a yellow liquid. The soda can be added during or after the slaking. This lime has been used in the experimental tannery of the University of Leeds on two packs of calfskins for chrome tanning, using sulphur and soda calculated to replace 5 per cent of sodium sulphide on weight of lime; the goods were ready for unhairing in four days, and as far as could be seen there was no difference between these skins and skins unhairied with sodium sulphide. The lime was also used on

one pack of hides for chrome sole leather. In this case more soda was added to the lime in order to increase the swelling. The hides were unhairied in four days. It has also been used for skins intended for vegetable tanned dressing leathers with equally good results. From these experiments it seems that these two materials would be a good substitute for sodium sulphide, with the advantage that the swelling can be controlled by increasing or decreasing the amount of soda, if more or less swelling is required than is given by sodium sulphide alone. By the omission of the soda an effect very similar to that of an "arsenic lime" is obtained.

Water Powers

Waterpower Laws in South and Central America.—The laws and regulations governing the use of water in Pan-American countries other than the United States have acted as a hindrance to the development of hydroelectric power, the same as in this country. A review of the laws of these countries together with the United States laws is given in an article by ROME G. BROWN, in the *General Electric Review*, May, 1916. The author states that the cause of the uneconomic waste in all the countries in question is that legislation for the regulation and use of water resources, instead of promoting their use, has become an obstacle to their use. Legislation has not kept pace with the progress in the science of water-power development and use.

The author gives first an account of the general sources of the laws and shows that they are all based on Spanish and French codes except the U. S., which is based on English law. He says "these different European sources of our American law of waters should be kept in mind in making any statement of the law of Pan-American countries. In the United States there is the greatest actual development, and also the greatest waste of water resources. There is also in that country the greatest amount of law and legislation with reference to water rights and at the same time the greatest lack of consistency or sanity in such legislation." He then gives a long discussion of the United States laws explaining the different powers of the Federal Government and the States in the matter of water power regulation, and showing how they have been obstacles in proper development. He says the present demand is for large power sites and that capital is waiting for proper protection.

The law in Spanish-American countries is then explained. In none of the countries of Spanish-America are the laws formulated in such a way as to attract private investment.

In Argentina the Federal power is, as in the United States, limited to the power to regulate commerce, and that is, with respect to streams, to regulate and protect navigation; but rivers are held to be the public property of the States. The uses of water by private parties are regulated by administrative authority under rules which may be modified or repealed. The enjoyment, therefore, of the use of waters is uncertain, and the rights of investors, even under authoritative permits, are precarious.

In Chile all rivers are "national property of public use." The use of public waters for power and other purposes is acquired by administrative concession. In 1907 a special statute was promulgated covering the subject of the "utilization of running waters for power." Under this statute the riparian owner may make a reasonable use of the waters which flow through his land. This right of use is not protected by law against a subsequent law, and the user is subject to certain regulations. The obstacles to development are uncertainty of tenure and possibility of burdens.

In Columbia the law is quite similar to that in Chile. In Cuba and Porto Rico rivers are part of the public domain and riparian owners have no rights except such as have been duly acquired under concessions legally made, or by prescriptive use. The laws have been codified and present a fairly reasonable certainty as to the terms upon which an investor may obtain a concession and operate under it. The laws appear to be more protective than most of the other countries under discussion.

In Uruguay the reservation of the right of the government to issue permits is not sufficient to encourage water power development; for the terms are subject to change, and insufficient protection is afforded against changes in the conditions of the authorization.

In Venezuela the public rights of navigation are made paramount, as in the United States. By a new constitution of 1914, the Federal Government now has control and investments are subject to changing legislation of the National Congress.

In Brazil, the general law is similar to that of Argentina. The Government is authorized to promote hydro-electric development for "federal" services, any excess to be sold for private use.

In Mexico the terms of concession, by which rights are obtained are too largely in the hands of the executive and subject to his caprice. Even under a stable government, the peculiarities of the Mexican law prohibit investment and development.

"The universal fault with existing policies of legislation, in these matters, is that the prospective investor, asking for a grant, concession, or permit, is viewed as one asking, for his own private benefit, a gift from the public. The theory is too much prevalent that, because water resources are a natural resource, they are, for that very reason, a purely public resource, and not by nature or in law for development in any other way than through the direct supervision of public authorities and for the exclusive and direct benefit of the public at large." Experience has demonstrated that utilization of wasting water powers cannot be accomplished by their development by the public authorities; but only through the capital of private investors. Such investors, however, rightly demand that security for their investment which shall afford to them reasonable protection against confiscation and loss of their investment, and against failure to receive fair returns thereon.

Recent Chemical and Metallurgical Patents

Iron and Steel

Nickel-Chromium Steel.—A special steel patented by JAMES CHURCHWARD, of Mount Vernon N. Y., and assigned to the Churchward International Steel Co., of New York City, has the following composition:

Steel, approximately	93.40%
Nickel, approximately	3.50%
Chromium, approximately	2.00%
Vanadium, approximately	0.35%
Manganese, approximately	0.50%
Silicon, approximately	0.25%

The steel contains approximately 0.10 to 1.00 per cent carbon. In manufacturing the alloy the metals themselves may be used or use may be made of ferro-alloys. Silicon is preferably mixed in the form of metal. The vanadium drives out occluded gases and also imparts elasticity when present up to 0.75 per cent. The silicon furnishes homogeneity and fineness of grain. The alloy is stated to be useful for deck plates for war vessels, and may be used as armor plate. Other uses are in shafting, and in general where resistance to impact,

shock and vibration are required. (1,181,570, May 2, 1916.)

Chloride Electrolysis

Caustic Soda and Chlorine Cell.—An electrolytic diaphragm cell with several interesting features is patented by HOWARD M. DUBOIS of Detroit, Mich. It is assigned to Pennsylvania Salt Manufacturing Company (compare cell patented by Arthur E. Gibbs and described in our issue of May 1, 1916, page 540). The cell can best be explained by reference to the sectional illustrations

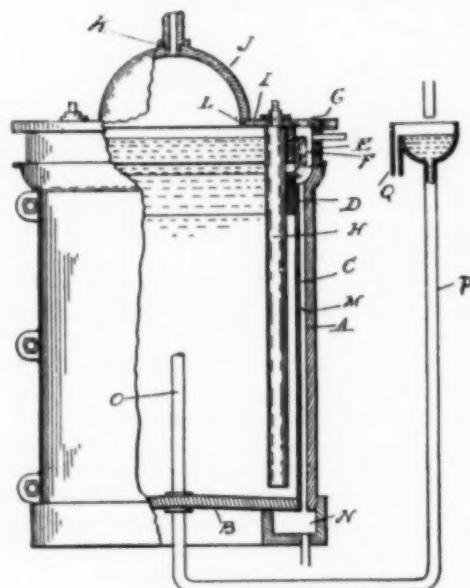


FIG. 1. SECTIONAL ELEVATION OF CELL

shown in Figs. 1 and 2. The outer casing A is composed of segmental metallic plates bolted together and forms the cathode. B is a non-metallic head at the bottom of the cell. The diaphragm C is cylindrical and is made of asbestos. D, E and F are rings of insulating material which form a trap above the diaphragm to allow the anode liquor to flow down between the diaphragm and cathode and prevent the hydrogen gas from entering the anode space. The dome-shaped member, J, serves to collect the chlorine and prevent any disruption of the anode from explosions. On account of the dome

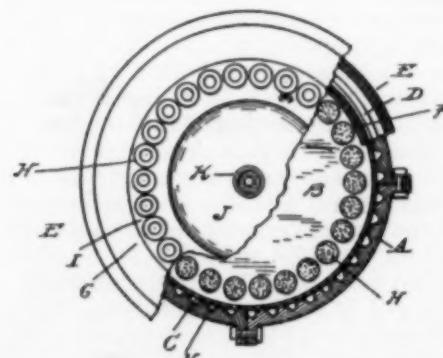


FIG. 2. SECTIONAL PLAN VIEW OF CELL

being the least resistant element of the cell to pressure, it will simply blow off in case of an explosion. The anode H is formed of a series of carbons arranged around the cell inside the diaphragm. The electrolyte is introduced through pipe O, and the proper level is kept in the cell by the hydrostatic column P. The inner side of the casing A is provided with grooves M (see Fig.

2), which form channels connecting the upper ends of the cell with a channel *N* at the lower end. These grooves greatly increase the cathode surface. The flow of electrolyte is continuous, and the caustic formed is drawn off at *N*. Hypochlorites are converted back to chloride by the action of the hydrogen in the overflow space before they can injure the cathode. (1,178,501, April 11, 1916.)

Electrolytic Cell for Nickel Extraction.—An electrolytic diaphragm cell is patented by FLOYD J. METZGER of New York City (one-third assigned to Hal. T. Beans and one-third to M. C. Whitaker of New York City). The cell is shown in cross-section in Fig. 3. Any suitable containing vessel 1 is used with carbon anodes 2, 2. The cell is described in connection with nickel extraction, and 3 represents a nickel cathode. The diaphragm 4 is of seasoned birchwood, formed by milling tools into a cup. The walls are about $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, and the grain runs lengthwise of the sides, so that the end of the grain is presented at the bottom. This is done to prevent resistance to the current, and the current efficiency is high with the grain cut in this manner. In connection with nickel extraction a solution of nickel chloride, sp. gr. 1.3, made by treating a nickel ore with hydrochloric acid, was electrolyzed. The diaphragm keeps the chlorine formed at the anode away from the deposited nickel, while at the same time allowing the electrolyte to pass through. In one test a deposit of

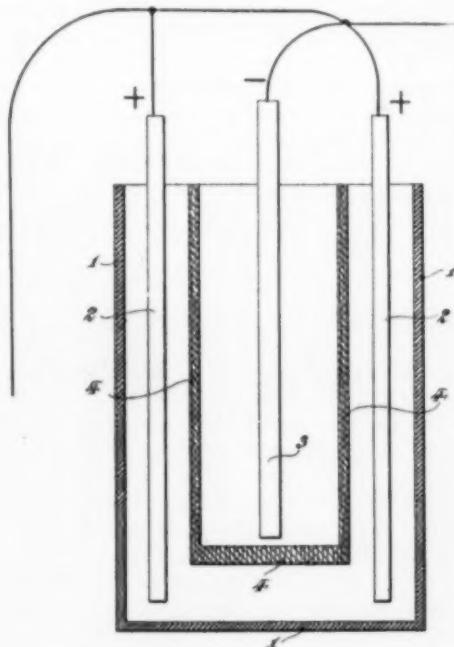


FIG. 3. CROSS-SECTION OF DIAPHRAGM CELL

33 gr. of nickel was obtained in three hours with a current of from 10 to 10.5 amp. and about 4.5 volts. The cathode surface was about 15 sq. in. (1,178,591, April 11, 1916.)

Hypochlorite Cell.—In a patent of J. F. WEBB, of Battersea, London, and WILLIAM WILLIAMS of Enham, England, an apparatus is described for the production of sodium or magnesium hypochlorite from chlorides of these metals. The cell consists of a receptacle for holding the solution, anodes of greatly compressed Acheson graphite, and cathodes of either the same material or of a suitable metal. The anode and cathode are separated by a plate of slate or porcelain. In order to isolate the hydrogen evolved at the cathode from the bulk of the electrolyte, orifices are made in the cathode and

deflectors are placed in these orifices. Referring to Fig. 4, which is a sectional elevation of the cell, the anode is shown at *d* and the cathode at *e*. The operating partition is shown at *f*. Above anode *d* a section, *d'*, of non-conducting material is placed to prevent the dispersion of the gases evolved at the electrodes. The deflectors

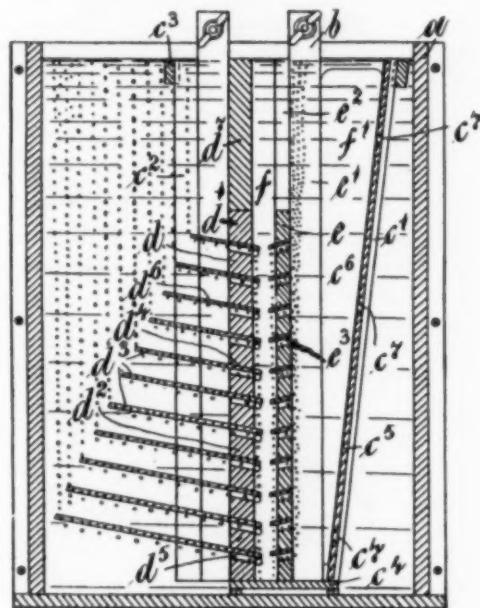


FIG. 4. HYPOCHLORITE CELL

d' and *e'* are placed in orifices in the anode and cathode respectively, and conduct the hydrogen from the cathode to the other side of the cathode from which it is generated, and it passes off at the top as indicated by the dots. The plates *c* is provided to close up the cathode chamber.

The oxygen from the anode is used to keep the solution in circulation, and passes along the deflectors as shown. (1,175,572, March 14, 1916.)

Copper

Electroplating With Copper.—A method of depositing copper which is designed to reduce the time of obtaining the required deposit in plating is patented by S. C. BABCOCK, of Hamburg, N. Y., and E. W. HAGMAYER, of Lackawanna, N. Y. No special apparatus is required. The novel feature of the process consists in the use of a solution of copper sulphate, containing sulphuric acid, creosote, phenol, crysyl hydrate or cresylol, phlorol, and gaiacol. The addition of these phenolic homologues causes a harder and firmer deposition and causes the copper to deposit in the smallest indentations. The bath is made up in the usual way, having about 270 pounds of copper sulphate dissolved in about 240 gallons of water. To this is added about 49 ounces of phenol sulfonic acid, properly prepared so that the phenol is thoroughly combined with the sulphuric acid. The voltage is between three and four volts and the current is about 750 amperes to a 140-gallon tank. The current density is somewhat variable, and can be varied depending upon the acidity of the solution. Operation and test of these improvements are claimed to show a time-reduction over previously known methods of about fifty per cent, and as above stated, the deposition is much more perfect and of greater density. The method is applicable to making halftones, electrotypes, in covering wires for electrical conductors, and for lining tanks and pipes with copper. (1,174,466, March 7, 1916.)

Zinc

The extraction of zinc from its ores by means of a solution of SO_4 is patented by HENRY T. DURANT, of London, England. The flow-sheet of the process is given in Fig. 5. Oxidized or carbonate ores of zinc are directly amenable to the process, but sulphide ores must first be roasted to oxide or sulphate. The sulphurous gases from the roasting operation are used as a solution of sulphurous acid to extract zinc from the ore. The

nion. The charge is introduced through a manhole. After the charge has been blown for a certain period, the converter may be rotated or oscillated to break up the charge and allow it to settle again on the grate in a new position, after which another period of blowing ensues. (1,172,321, Feb. 22, 1916.)

Treatment of Lead or Irony Zinc Ores.—For the production of cleaner spelter from zinc ores containing considerable iron or lead, or both, CHARLES A. H.

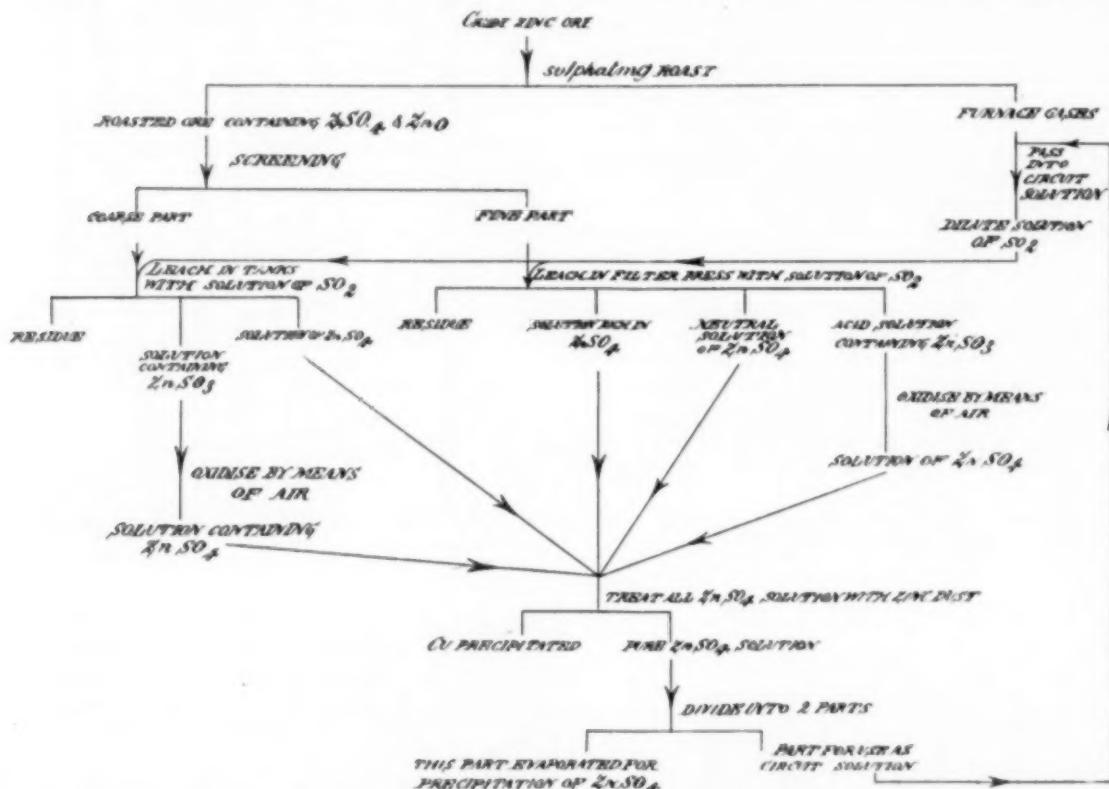


FIG. 5 PROCESS OF EXTRACTING ZINC FROM ORES

present patent covers improvements on the process previously disclosed. The ore is roasted to contain as large a percentage of sulphate as possible and the operation is preferably conducted in a reverberatory furnace. The gases are absorbed in circuit solution which is used to extract metal from the ore. The finely divided material is treated in filter presses while the coarse is leached in vats. The first solutions obtained will be rich in zinc sulphate, but the last may contain mainly sulphite, which will have to be oxidized by means of air. Copper contained in the solution is removed by precipitation with zinc dust. The recovery of zinc is effected as zinc oxide by evaporation of part of the solution, while the balance is diluted with wash solutions and returned to the absorption tower and then to the leaching vats or filter presses. (1,180,765, April 25, 1916.)

Production of Zinc Oxide.—An improvement in the method of "blowing" zinc ores mixed with fuel for the production of zinc oxide is claimed in a patent granted to FRIEDRICH C. W. TIMM, of Hamburg, Germany. The object of his invention is to provide means whereby the mixture under treatment may be kept in a physically homogeneous state, so that cracks and blowholes will not occur. He therefore makes use of a spherical converter mounted on hollow trunnions through one of which the air is blown, while the other forms an exit for the zinc oxide. The converter has a grate which is normally at the bottom of the converter, and beneath which the air is supplied by a connection with the trun-

nions. The charge is introduced through a manhole. After the charge has been blown for a certain period, the converter may be rotated or oscillated to break up the charge and allow it to settle again on the grate in a new position, after which another period of blowing ensues. (1,166,447, Jan. 4, 1916.)

Proper Care in Use of Crucibles in Foundries

The securing of the proper clays in sufficient quantities has troubled the crucible maker greatly since the beginning of the war, and made it impossible to supply the highest grade crucibles. Better clays, however, are being secured at present and with their use better results will be had in the foundry and longer lived crucibles will result.

It rests, however, with the user, in a measure to improve the present unfortunate state of affairs and this can be done in the following ways:

Greater care must be given in annealing—more time must be consumed, after the crucible is received, before it is put into service, and smaller crucibles used than those which the foundry has been in the habit of using. In past years all brass rolling mills, crucible steel casters and jobbing shops thought nothing of having six

months or a year's stock of crucibles ahead of their wants—seasoning and drying. To-day, a crucible is put into active service as soon as it is received.

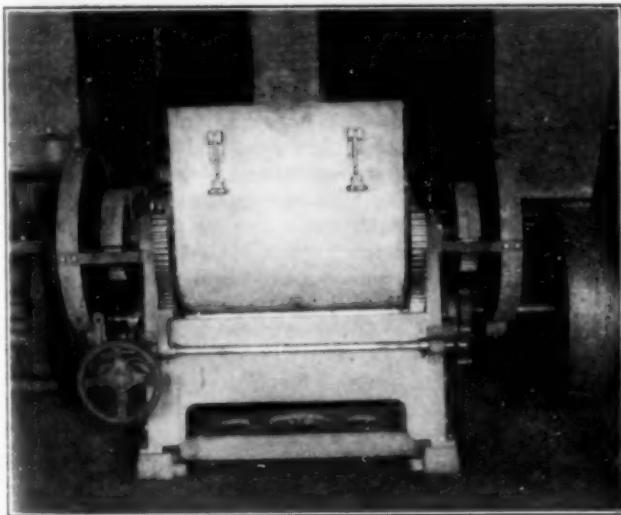
The native clays now used by the crucible maker have made the crucible more frail and tender than were those made from foreign clays—more likely to crack on sudden heating and cooling. Therefore, more than ordinary care must be used by the melters in the handling of American-clay-made crucibles.

Crucibles should not be cooled down too rapidly, any more than should the heating up be done too quickly. It is a good plan to return the crucible while it is still hot, after the day's work is done, to the furnace from which, of course, the coal has been dumped. By doing this, the strain in the cooling will not be as severe and the crucible will not crack so early in its life.

The smaller the crucible is, the greater are the number of heats that can be secured. Therefore, if a crucible of a size or two smaller than that which is generally used is adapted, better values and less disappointments will be the result. For instance, if a foundry uses a No. 400 pot, it should adapt a No. 300 or a No. 225—or in a shop where No. 60's are the rule, a No. 45 or a No. 50 should be used. In this way both caster and crucible maker will be relieved of the hundreds of annoyances and complaints that have occurred in the last few months.

Mixer

The adjoining illustration shows one of the strongest heavy-mass mixers on the market to-day. The cast-iron cylinder section is provided with a jacket so that the charge of the mixer may either be artificially cooled by the use of brine or cold water in the jacket or may be heated by circulating steam or hot air. This machine is particularly adapted for the mixing of smokeless powders, such as cordite, lydite, or in fact for all classes of nitro-cellulose compounds. But this mixer is also well adapted for handling artificial silk, gutta percha, "electro mass," etc.



MIXER

The illustration shows a machine with a bowl capacity of 160 gallons. It has been so carefully designed that it is usually operated with less than 10 hp. All the gears are of high-carbon steel, machine-cut, while the bevel gears on the dumping mechanism are of nickel-steel and the worm wheel of bronze.

This mixer has been placed on the market by Mr. Paul O. Abbé, 30 Broad Street, New York City.

A Combination Boiler Meter

A boiler meter which is a combination of three separate meters in one casing each drawing its own record in a distinctive color on a 12" chart, is made by the Bailey Meter Co., Boston, Mass. This meter records

- (1) The rate of steam output from the boiler,
- (2) The rate of air flow through the furnace, and
- (3) The condition of the fuel bed.

It also correlates and compares these factors in such a simple manner that any fireman can readily understand the readings and be informed instantly of any needed change in the furnace or draft conditions to secure the best efficiency and maximum capacity. A photograph of an installation is shown in Fig. 1. Charts are shown in Fig. 2.

The steam flow is recorded by the red pen drawing a red record in the center section of the chart, the graduations being in per cent of the boiler's rated capacity on a uniform scale. This part of the meter is identical with the Bailey steam meter described in our April 15, 1916, issue. It operates upon the principal of measuring the pressure difference across a Monel metal orifice placed in a flange of the steam line.

The air flow is recorded by the blue pen drawing a blue record. This pen is located so that it travels immediately in front of and records just ahead of the steam flow. It is operated by the draft differential between the firebox and the uptake, but instead of reading in terms of draft it reads in terms of steam output. In other words, it gives the same reading and draws a coincident record with the steam flow so long as the right amount of air is used for combustion. If the air flow reads more than the steam flow it shows too much air and corresponds to low CO_2 ; if it reads less than the steam flow it means insufficient air and loss due to unburned gases. This is based upon the principle that air is a fuel just as coal is, and a certain evaporation should be obtained per pound of air. This standard is determined for each boiler and the meter adjusted accordingly.

The furnace indicator drawing a record on the outer section of the chart shows the conditions of the fuel bed. The fire is of the right thickness when this pen is on the shaded band, too thick when above, and too thin when below the band. This also is adjusted to individ-

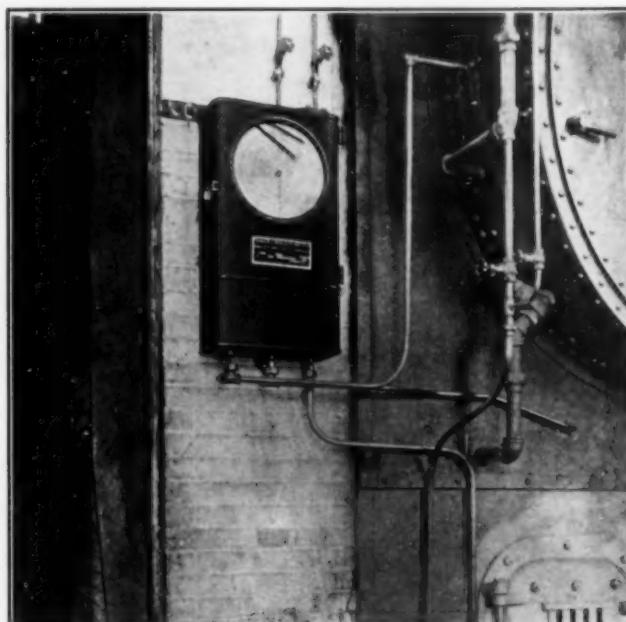


FIG. 1—METER INSTALLED IN BOILER ROOM

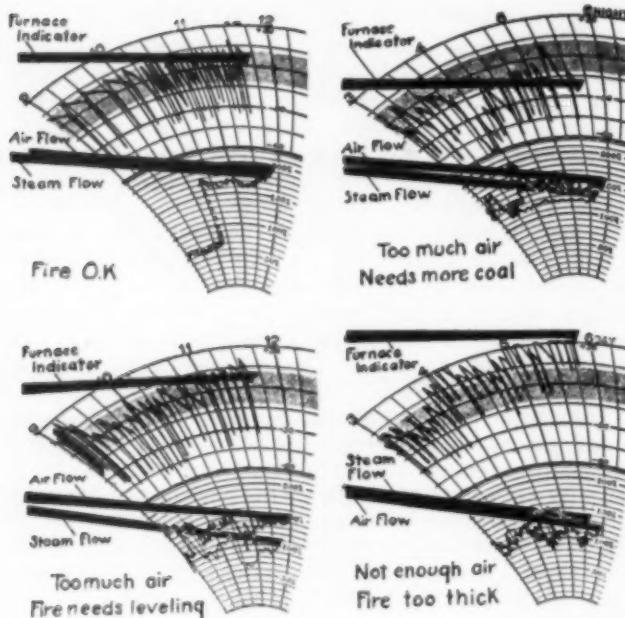


FIG. 2. ILLUSTRATIVE CHARTS

ual conditions after extensive tests have been made to determine the best kind of fire to carry. This furnace indicator is operated by draft pressures and is in reality a measure of the resistance of the fuel bed to the flow of air. It should not be confused with the drop in draft pressure across the fuel bed, for it includes the draft pressure in the uptake as well as the firebox and ash pit in such a way as to eliminate the effect due to the intensity of the draft or the rate of flow of air and responds only to changes in condition of the fuel bed. That is, the pen does not move when the damper opening or draft pressure varies from maximum to minimum unless the fire changes but when the fire burns too thin or develops holes, the recorder shows it regardless of the intensity of the draft.

Every part of the meter responds instantly to changes in any of the operating conditions. In a hand-fired furnace it plainly shows each opening of the fire door, cleaning of the fire, etc. When applied to stokers it brings out many very interesting points regarding the operation and control.

The meter is of very simple design and rugged construction.

Annual Meeting St. Louis Section, American Institute of Mining Engineers

The annual meeting of the St. Louis Section of the American Institute of Mining Engineers was held at St. Louis, Mo., May 20, 1916. There was an excellent attendance from all parts of the territory governed by the Section, members being present from the lead belt of Southeast Missouri, the Joplin zinc district, School of Mines at Rolla, Kansas City, and University of Illinois, Urbana. The day was devoted to trips to industrial plants and the evening to a dinner at which President L. D. Ricketts and Secretary Bradley Stoughton of the Institute were guests.

In the forenoon the party inspected the Koppers by-product coke ovens of the La Clede Gas Light Company in South St. Louis. The company manufactures gas for domestic and industrial use and recovers tar, ammonia and light oil from the distillate. These by-products are disposed of to local manufacturers who further refine them for various purposes.

A noon luncheon was held at the Mercantile Club,

after which a trip was made by special trolley cars to Granite City, Ill., where the plants of the National Stamping & Enameling Company and the Hoyt Metal Company were visited.

The annual banquet was held at the St. Louis Club and was followed by the business meeting and an address by President Ricketts. The following officers of the Section were elected for 1916-17: Chairman, Charles J. Adami; vice-chairmen, Herman Garlichs, Frank W. De Wolf and M. M. Valerius; secretary-treasurer, W. E. McCourt; members of executive committee, together with the foregoing, Albert W. Dickinson, Carroll R. Forbes, Charles T. Orr, F. D. Rash. The matter of inviting the Institute to hold a general meeting in St. Louis in 1917 was referred to the executive committee of the Section with power to act after consulting local operators and members to determine what support for the project would be forthcoming.

Dr. L. D. Ricketts addressed the Section on "The Present Conditions and Outlook of the Copper Industry in the West," and incidentally made reference to the copper industries of Chile, which he had recently visited. Beginning with the pioneer work in copper smelting done by Richard Pearce in Colorado, Dr. Ricketts traced the metallurgical development of the industry to the present time. The principal features of this development were the introduction of converting, first with acid and then with basic linings, the gradual enlargement of the reverberatory furnace, the beneficiation of very low-grade ores, the establishment of hydrometallurgy on a large scale, and finally the use of flotation. In the application of the latter process it has been found that its place in the metallurgical scheme depends on the ratio of concentration of the ore. For ratios of from 3:1 to 10:1, gravity concentration is called for as a preliminary process, with flotation as an accessory on slime and reground middlings and tailings. When the ratio rises to 25:1 or more, original fine grinding and flotation may become the primary process, followed by gravity concentration as a secondary process to recover coarse mineral which may have escaped flotation.

Referring to the future of the copper industry, Dr. Ricketts stated that the principal problems from a metallurgical point of view were the treatment of very low-grade sulphide and silicate ores, and the recovery of the valuable metallic and chemical constituents of smelter gases. An increased use of phosphate fertilizer will afford an outlet for the vast quantities of sulphuric acid which can be made from smelter fumes. In general the outlook for the copper industry is favorable, and with improvements in methods we may expect to be treating profitably ores containing as little as 0.75 per cent copper. Dr. Ricketts closed his remarks with a compliment to the local operators for their liberality in exchanging ideas and information, and showed the advantages that accrue from such a custom.

Copper Chemical Equipment.—Another indication of the present rapid progress of industrial chemistry in this country is the entry of the old and well-known copper-smith firm of August Roos' Son of 429 East Ninety-first Street, New York City, into the chemical engineering field. This firm is now equipped to design and construct distilling, evaporating, dissolving and extracting apparatus for the chemical and allied industries.

The Chemical Construction Company of Charlotte, N. C., has increased its capital stock from \$10,000 to \$50,000 owing to the rapid expansion of its business.

The Goldschmidt Detinning Company announces the removal of its offices to The Equitable Building, 120 Broadway, New York City.

Industrial Notes

Pig-Iron manufacturers in the Birmingham, Ala., district are sold up pretty well for the balance of the year, and in all probability a scarcity of iron in this district will become a reality. There are already a number of inquiries for 1917 delivery.

Sulphuric Acid in 1915.—The production of sulphuric acid in the U. S. in 1915 is given in a recent Geological Survey report by W. C. Phelan, as follows: 1,518,271 short tons of 50, 52, 53 and 55 deg. were produced. This compares with 1,628,402 short tons of these strengths in 1914. The production of 60 deg. acid was 657,076, which compares with 551,955 short tons in 1914. The production of 66 deg. was 1,019,024 short tons, which compares with 916,192 short tons in 1914. Of other strengths there was produced 189,795 short tons, comparing with 65,890 short tons in 1914.

The Kalbeperry Corporation, New York, have opened a new office in the Metropolitan Building, 31 Union Square, West, for the purpose of conducting a chemical engineering business in investigation, design and operation. Besides the strictly chemical work the company will handle buildings and apparatus pertaining to same.

Possibilities of South Africa for Electrochemical Industries.—The development of resources committee of the South African Institute of Electrical Engineers has just issued a report on the possibilities of establishing certain electrochemical industries on a commercial basis in South Africa, according to Commerce Reports. In reviewing the document the *Board of Trade Journal* states: "The report does not attempt to cover the whole subject, but is confined to South Africa's chief industries, agriculture and mining. These industries, taken together, now require annually more than £2,000,000 (\$9,733,000) worth of chemicals, all of which are imported in the form of fertilizers, cyanides, and nitrates. The essential elements for the successful manufacture of the compounds are cheap electricity, abundant coal and limestone, and all these, together with the necessary labor, are available in South Africa. Furthermore, the local market is to a considerable extent protected from competition by the necessarily high cost of transport for imported articles, as well as by the customs duties. The report proceeds to consider the prospects of producing calcium carbide and cyanamide and derivatives of cyanamide, and the conclusion is reached that these products can be profitably manufactured in South Africa provided the necessary raw materials are available at reasonable cost. It is therefore urged that an early investigation should be undertaken with regard to the location, quality and cost of production of these raw materials." It is reported that a factory has been established at Vryheid (Natal) for the production of ammonium sulphate. Plant, stated to be capable of making 5000 tons annually, has been laid down at a cost of £350,000 (\$1,703,275).

The Richardson-Phenix Co., Milwaukee, Wis., has issued Bulletin No. 5, April, 1916, describing oil filters in standard sizes of 1 to 800 gallons hourly filtering capacity. The catalog is devoted principally to a description of Richardson-Phenix Multiple Type oil filters having capacities of 1 to 35 gallons per hour.

The Castner-Kellner Alkali Company and **Brunner, Mord & Co.**, of England, are effecting a consolidation of their interests in order to meet foreign competition after the war. The combined capital will be about \$42,500,000.

The Viscose Fibre Co. is planning a large addition to its plant at Marcus Hook, Pa.

Regulation of Electrotyping Solutions.—The second

edition of circular 52 has been prepared by the Bureau of Standards. It has been entirely rewritten, the additional sections being devoted principally to a discussion of the effect of various factors upon the deposition of copper in electrotyping baths, based upon the literature on this subject, and upon recent investigations by the Bureau of Standards. The limits of composition of solutions, temperature and current density are defined within which copper having the required tensile strength and ductility may be obtained. The circular also includes conversion tables for Fahrenheit and Centigrade temperatures, metric and customary units, and specific gravity and degrees Baumé. Definitions of important electrical terms are given, and also tables showing the weight and thickness of copper deposited by a given current in a specified time.

The Robeson Process Company, which recovers products from waste solutions of paper mills is increasing its production by the installation of a plant at Covington, Va. It is installing an evaporating plant recently completed in the shops of the Swenson Evaporator Company. This is a quadruple effect of a type very similar to that used for evaporating sugar solutions.

Alcohol from Waste Sulphite Liquor.—On account of the present war prices of alcohol, one of the sources of raw material being investigated is the waste sulphite liquor from the paper mills. The Kimberly-Clark Paper Company, Neenah, Wis., has installed a preliminary plant for alcohol production under the Marchand process with the apparent purpose of increasing its proportions if satisfactory. It seems that this process promises very much higher yield of alcohol per ton of waste than has hitherto been obtained. It is claimed that the chemical means used bring about results which were not believed possible. Mr. Charles Marchand will be recalled by some people from his work on peroxide. Briefly the alcohol process includes chemical treatment of sulphite liquor, reduction of its volume by concentration in the standard Swenson evaporator, and subsequent distillation by the ordinary known processes.

Research into the Development of Canada's Natural Resources

Mr. Arthur D. Little of Boston, Mass., and the organization of Arthur D. Little, Inc., have been retained by Lord Shaughnessy, president of the Canadian Pacific Railway Co., to assist in carrying out extended plans for a scientific research of Canada's natural resources. While there has been a considerable development, only a small part of Canada's resources has been really exploited, and, aside from the investigation of the country's resources by the government departments, it has been fragmentary.

It is Lord Shaughnessy's belief that with properly guided research the opportunities afforded by the natural resources of Canada can be demonstrated so as to interest capital and bring about a great industrial development, and it is for this work that Mr. Little has been retained.

In order to provide proper facilities for this work, a Dominion charter has been taken out for Arthur D. Little, Limited, and offices have been fitted up in Montreal.

The H. M. Lane Co., Detroit, Mich., are preparing plans for a continuous malleable foundry for the Timken-Detroit Axle Co. This plant will be located in Canton, Ohio. It is planned to arrange to handle the product with greatest efficiency so as to reduce labor and improve quality.

Personal

Messrs. Clarence L. Burger and W. H. Crichton Clarke, formerly associated with the late Edward B. Moore, former commissioner of patents, in the firm of Moore & Clark, announce that they have associated themselves together under the firm name of Burger & Clarke, and will continue in the offices of Mr. Burger, 2 Rector Street, specializing in the law of patents, trademarks, and copyrights, including the soliciting of United States and foreign patents.

Mr. Charles A. Chase of Denver is reported to have suffered a broken wrist and minor injuries as the result of an automobile accident in Bummer's Gulch, Boulder County, Col. Mr. Chase was on his way to the tungsten district when the accident occurred due to failure of the brakes to hold on a steep hill.

Mr. Hardy S. Ferguson of New York City is engineer in charge of the erection of new pulp mills for the St. Maurice Paper Company, near Three Rivers, Quebec. This is to include both sulphite and sulphate mills of considerable capacity. These installations are expected to be representative of the most recent ideas and developments and will in every respect be thoroughly standardized as to their general layout and the general design of their equipment. Mr. P. B. Sadler of Chicago, who has been awarded contracts for the evaporating equipment, is of the opinion that this mill will not be closed to the public for purposes of secreting technical facts.

Mr. J. R. Finlay was selected to deliver the address to the graduating class of the Colorado School of Mines on May 26.

Mr. Charles L. Foster, formerly manager of the Akron district for the Westinghouse Electric & Manufacturing Company, has taken charge of the sales department of the Electric Furnace Company of Alliance, Ohio, under the title, manager of sales. Mr. Foster has had a long experience in the electrical line, having been for thirteen years with the Westinghouse Company.

Prof. E. C. Franklin of Leland Stanford, Jr., University, has had an unfortunate laboratory accident, through an explosion in his laboratory, which caused burns and other injuries. Later news are more reassuring, and the fact is announced that Professor Franklin is steadily recovering in the hospital, and that the accident will not leave serious consequences.

Mr. H. S. Kimball has been elected president of the Aetna Explosives Company, Inc., succeeding A. J. Moxham, who becomes chairman of the board. Mr. Kimball is also president of the American Zinc, Lead & Smelting Co.

Dr. A. D. Little has been appointed head of the bureau which was recently organized in Montreal, Canada, to co-ordinate the work of scientific research in Canada.

Dr. Ralph H. McKee has resigned as professor of chemistry at the University of Maine and will take charge of the research department of the Tennessee Copper Co., with laboratory at Ridgefield Park, N. J.

Mr. D. T. MacLeod has opened an office at 50 Pine Street, New York, as consulting engineer in the design and construction of by-product coke-ovens. Mr. MacLeod was formerly chief engineer of the United Coke & Gas Co., American Coke & Gas Construction Co., and Otto Coking Co.

Mr. Philip Schmitt, formerly superintendent of electric furnaces at the United Steel Co., Canton, Ohio, is now in charge of a new Héroult installation at the Harrow Spring Co., Kalamazoo, Mich.

Dr. Joseph Struthers, formerly secretary of the American Institute of Mining Engineers has been appointed treasurer of the Federal Export Corporation, which is affiliated with the Federal Shipping Co., Inc.

Mr. A. W. Taylor, formerly superintendent of the open-hearth department of the Gulf States Steel Co., Gadsden, Ala., has been appointed metallurgist with the Jones & Laughlin Steel Co., Pittsburgh, Pa.

Mr. Wilbur S. Wilding has been appointed eastern manager of the International Filter Co., Chicago, with offices in the Woolworth Building.

Mr. George J. Young has been elected professor of metallurgy at the Colorado School of Mines, beginning September, 1916. Mr. Young was formerly director of the Mackay School of Mines, Reno, Nev., and lately professor of mining at the University of Minnesota.

Book Reviews

The Canadian Mining Manual—1915. Edited by Reginald E. Hore, editor of the *Canadian Mining Journal*. Price, \$2.00. Toronto: The Canadian Mining Journal.

This annual contains statistical and descriptive data relative to the mining industry of Canada, and is designed to furnish reliable information to those who may be interested but not well informed on the subject. The work is a compilation from many sources. The statistics given are final for 1914 and estimated for 1915. The first chapter is devoted to a general review of progress and conditions in 1915, the various metallic and non-metallic products being considered in alphabetical order. This is followed by a review according to Provinces. The mining companies operating in Canada are then listed alphabetically, giving data on property, plant and personnel of staff. In the last division of the book the operating companies are listed according to product. The manual is a useful work of reference on the Canadian mining industry.

The Flotation Process. Compiled and edited by T. A. Rickard. 364 pages, 79 illustrations. Price \$2.00. San Francisco: The Mining & Scientific Press.

This is a compilation by the editor of *Mining & Scientific Press* of articles on the subject of flotation that have appeared in that magazine during the past few months. As the editor states in his preface, the book "has been prepared to meet the need of the hour," supplementing the information contained in earlier editions of Hoover's work on the subject.

The first paper is by the editor, giving a general introduction of patentees of the process. In the subsequent papers, various authors attempt to elaborate the introduction to the subject and covering its history, physics and methods of application as revealed in the series of flotation with a view to developing a scientific method of study and procedure. Since the several contributors approach the subject from different points of view, it is inevitable that some of their suggestions are not wholly in accord and that apparent contradictions confront the reader as he passes from one article to another.

Some of the papers relate more strictly to the commercial application and results of the flotation process; among these one of the most important is the contribution by Messrs. Butters and Clennell on the cyanidation of flotation concentrates.

The experimenter will be interested in Mr. Ralston's description of methods and machines for testing ores by flotation. This paper covers a great variety of devices for floating ores, and will be of value to the student or to those engaged in systematic testing.